BASIN-WIDE POLLUTION INVENTORY FOR THE ILLINOIS RIVER COMPREHENSIVE BASIN MANAGEMENT PROGRAM

FINAL REPORT

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VOLUME 1
Estimating Nonpoint and Point Source Loading to the Upper Illinois River Basin

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CHAPTER 1. INTRODUCTION

Surface runoff from agriculture, mining, oil and gas exploration, construction, Silviculture, and other related activities contribute significant amounts of phosphorus and sediment to our surface waters. These nonpoint source pollutants have been shown to impair surface water quality (Newman, 1995; Puckett, 1995; Wagner et al., 1996). To identify and/or quantify potential nonpoint sources of pollution in a cost effective manner, computer models and geographic information systems can be utilized. In addition, computer models can be used to target critical source areas of sediment and phosphorus for priority treatment. Given limited resources, the implementation of Best Management Practices (BMP's) in these critical source areas can minimize the potential for off-site water quality impacts.

The purpose of this project is to provide assistance in the implementation of the Illinois River Watershed Implementation Program, which is part of Oklahoma's Section 319 Management Program. This project is one component of a comprehensive program that addresses the wide range of pollution sources within the Illinois River Basin. The overall goal of the comprehensive program is to improve and protect the water quality of the Illinois River, which has been designated a Scenic River by the State of Oklahoma, and Lake Tenkiller. The Illinois River Basin is in northwest Arkansas and northeast Oklahoma. The Illinois River drains approximately 1.1 million acres, which includes Benton, Washington and Crawford Counties, Arkansas, and Delaware, Adair, Cherokee, and Sequoyah Counties, Oklahoma. The basin contains approximately 49 percent grassland, 44 percent forest, 1 percent cropland, 0.3 percent orchards and vineyards, 3.5 percent urban, and 2.2 percent other land uses. The location of the Illinois River basin is shown in Figure 1.1.

There are currently a variety of distributed parameter watershed and basin scale models available to predict sediment and phosphorus loading to surface water. Examples of these models include AGNPS (Young et al., 1989), ANSWERS (Storm et al., 1988), SQWRRB-WQ (Arnold et al., 1990), and SWAT (Arnold et al., 1993). These models require a significant number of input parameters, and data to accurately estimate these parameters are often not available. When detailed data are available, these more sophisticated models may provide more accurate results. However, the uncertainty in model predictions due to parameter uncertainty may out weigh the use of simpler methods of estimating sediment and phosphorus loading (Heatwole and Shanholtz, 1991; Shanholtz et al., 1990; Hession and Shanhotz, 1988).

Presented is a modeling study that utilizes a less complex model than existing watershed scale models called the Spatially Integrated Model for Phosphorus Loading and Erosion (SIMPLE). SIMPLE estimates runoff volume, sediment yield, and dissolved and sediment-bound phosphorus loading to the stream. In the following study we apply SIMPLE to the Upper Illinois River Basin.

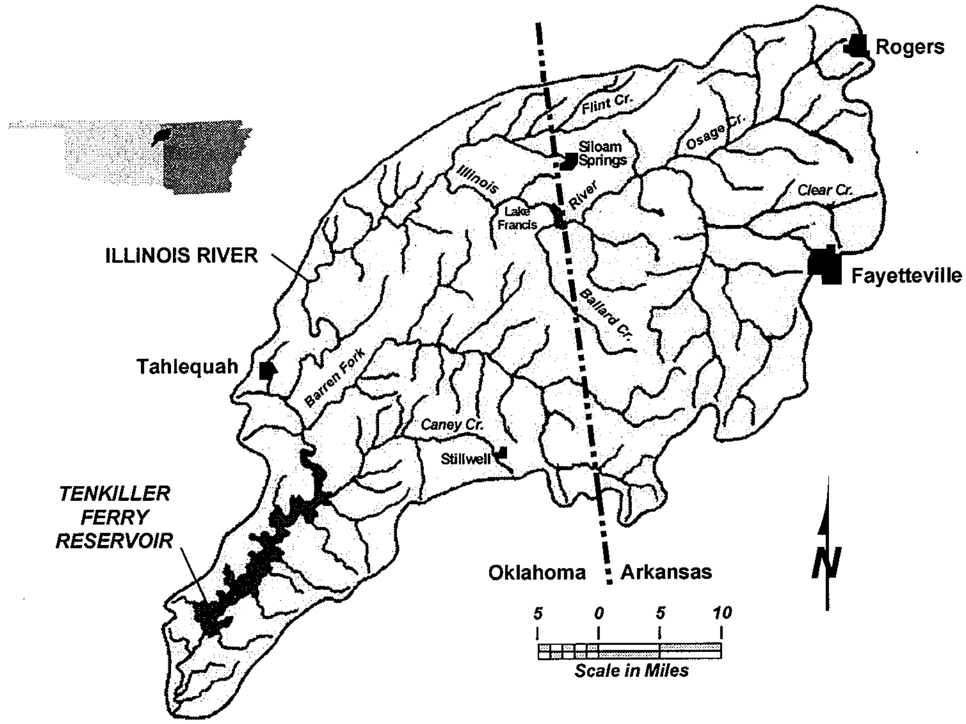


Figure 1.1 Location and description of the Illinois River basin in northeast Oklahoma and northwest Arkansas

CHAPTER 2. NONPOINT SOURCE LOADING

2.1 MODELING FRAMEWORK

2.1.1 SIMPLE - Overview

Surface runoff from agriculture, mining, oil and gas exploration, construction, Silviculture, and other related activities contribute significant amounts of phosphorus and sediment to our surface waters. These nonpoint source pollutants have been shown to impair surface water quality. To identify potential nonpoint sources of pollution in a cost effective manner, computer models must be used that integrate state-of-the-art technologies, such as, geographic information systems (GIS) and remote sensing. These computer models can be used to target critical source areas of sediment and phosphorus for priority treatment. Given limited resources, the implementation of Best Management Practices (BMP's) in these critical source areas can minimize the potential for off-site water quality impacts.

Many factors affect sediment and phosphorus losses from nonpoint sources, such as soil properties, application of fertilizers or animal wastes, soil phosphorus levels, rainfall, soil properties, crop type, cover condition and density, topography, livestock activities, and others. To accurately and efficiently account for these physical, chemical, and biological factors at a watershed or basin scale, a computer model was employed called the Spatially Integrated Model for Phosphorus Loading and Erosion (SIMPLE). SIMPLE is a distributed parameter modeling system developed to estimate watershed-level sediment and phosphorus loading to surface water bodies. The system encompasses a Phosphorous Transport Model, a Digital Terrain Model, a data base manager, and a menu driven user interface.

SIMPLE is used to target and prioritize nonpoint sources of sediment and phosphorus and to evaluate the effects of BMP's. The modeling system has a fully integrated data management tool, which efficiently manipulates large amounts of information. In addition, a GIS is used to visualize model results, and to develop data layers that are used by SIMPLE to estimate model parameters. Below is an overview of the SIMPLE model. Additional detail on the model and its application can be found in Sabbagh et al. (1995), Storm et al. (1995), Sabbagh et al. (1994), and Chen et al. (1994).

2.1.2 SIMPLE Modeling Framework

SIMPLE is a modeling system consisting of a Phosphorous Transport Model (PTM), a Digital Terrain Model (DTM), and a database manager (Figure 2.1). The system components communicate with each other via interface software, a standard SUN workstation X-view windows application. The interface significantly enhances the efficiency of command executions allowing the user to define the input and output parameters and to develop the required data bases.

The SIMPLE modeling system can be used in conjunction with the GRASS GIS (CERL, 1988). The format of the spatial data required by the system are the same as the format of ASCII files generated from GRASS raster data. However, SIMPLE does not require GRASS to run; it can be used independently, as long as the data files are formatted correctly. Spatial information generated by SIMPLE can be exported for display in GRASS.

SIMPLE provides two scales at which to simulate sediment and phosphorus loading: cell scale and field scale. A cell is the smallest element of a map in which the data are stored. A field is a group of adjacent cells with homogeneous soil and land use characteristics. The field-based option requires less simulation time because there are fewer fields than cells. However, errors may be introduced if there are significant variations within a field.

Conducting SIMPLE simulations involves defining the simulation period, the simulation scale, and the type and level of outputs. If cell-scale simulations are to be conducted, the required topographic information and soil characteristics for each cell can be generated by the DTM and the soil data manager. Simulation results can be summarized in tables, and/or graphically displayed.

SIMPLE provides in tabular form monthly and annual estimates of runoff volume, sediment yield, and soluble and sediment-bound phosphorus loading to streams. Such tables are generated field by field and for the entire watershed. The spatial distribution of runoff volume, sediment yield, and phosphorus loading estimated for the entire simulation period can also be displayed graphically.

The system components are briefly described below. Details on the system components and framework are presented in later chapters.

2.1.2.1 Phosphorus Transport Model

The phosphorus transport model (PTM) is a physically based mathematical model developed to evaluate the potential phosphorus loading to streams from areas with homogeneous soil and management characteristics. The model operates on a daily time step. Independent simulations are based on factors such as rainfall, soil characteristics, fertilizer and animal waste applications, and topographic characteristics. The PTM is divided into four modules: runoff, soil erosion, phosphorus loss and delivery ratio.

1. Runoff Module: The runoff component is based on the SCS curve number method (SCS, 1985), where runoff volume is a function of rainfall volume and the curve number (CN) value. The CN value for a particular day is adjusted to reflect antecedent soil moisture conditions.

2. Sediment Loss Module: The Universal Soil Loss Equation (USLE) is used to estimate soil erosion caused by rainfall and runoff (Wishmeier and Smith, 1978). The USLE is a function of soil erodibility factor (K), cover and management factor (C), supporting conservation practice factor (P), slope length factor (L), slope steepness factor (S), and the rainfall/runoff factor (R). The K, P and C values are inputs, and L and S are calculated from the land slope (θ) and the slope length (λ) (McCool et al., 1989; McCool et al., 1987). The slope (θ) is computed by the DTM model described below. The slope length, λ, is a user specified input. To calculate the R factor for the USLE, the equation described by Cooley (1980) is adopted. This equation provides an estimate of the R factor for each storm.

3. Phosphorus Module: This module estimates daily phosphorus status associated with the application of commercial fertilizer and animal manure. The processes considered in the module include diffusion of phosphorus into surface runoff, and the exchange between mineral and plant available phosphorus. A daily mass balance is conducted on the top one cm of the soil profile. The phosphorus content in the soil is updated by adding phosphorus contained in the applied commercial fertilizer or animal waste and subtracting phosphorus leaving the field in runoff and sediment. The model estimates the desorption of phosphorus in the soil matrix and the concentration of phosphorus in surface runoff using a linear isotherm (Williams et al., 1984).

4. Delivery Ratio Module: The amount of sediment and sediment-bound phosphorus leaving the field may be reduced along its route to the final receiving water body due primarily to biological stabilization, deposition, and trapping. Heatwole and Shanholtz (1991) developed a delivery ratio relationship to account for deposition and trapping. The delivery of phosphorus is a function of the distance to the stream (D) and the slope along that distance (θ_D). The values of D and θ_D are computed by the DTM.

2.1.2.2 Digital Terrain Model

The digital terrain model (DTM) provides estimates of the topographic parameters required to run the PTM. DTM uses digital elevation data (DEM) to estimate θ, D and θ_D. The DTM is divided into six components that contain procedures to: (1) detect and fill depressions, (2) define flow direction, (3) calculate flow accumulation values, (4) delineate channel networks, (5) define drainage boundaries, and (6) extract cell and drainage characteristics such as slope, and flow path length and slope.

1. Filling Depressions: The procedure used to generate a depressionless DEM is based on

techniques developed by Jenson and Domingue (1988). The depressionless DEM is generated by filling single-cell depressions, identifying the cells constituting multi-cell depressions, and filling multi-cells depressions. Depressions are filled by raising their elevation values to the level of lowest neighbor elevation.

2. Flow Directions: The flow direction for a cell x is assigned on the basis of the steepest elevation gradient away from the cell. The gradient is taken as the change in elevations between cell x and the neighboring cell divided by the distance between the centers of the two cells. There are eight possible flow directions (Greenlee, 1987).

3. Flow Accumulations: The flow direction file is used to calculate the flow accumulation value for each cell. The flow accumulation value for cell x represents the total number of cells that have upstream flow paths passing through it. Cells located in lower elevations, such as channels, have higher accumulation values.

4. Network Delineation: Channel networks are identified and enumerated based on the flow accumulation values and on a user defined threshold network density. Cells with flow accumulation values equal to or greater than the threshold value are identified as channel network cells. Once the channel network cells are defined, the channels are numbered; then they are divided at junction nodes into a series of branches (Storm, 1991). The initial junction for branch enumeration is found by following the maximum flow accumulation gradient. All first-order streams are enumerated sequentially, followed by the remaining stream orders. For hydraulic routing purposes, this ordering system allows the processing of all upstream branches prior to any downstream branch.

5. Watershed Delineation: This module identifies the watersheds in the study area and delineates their boundaries. Each watershed has one outlet or start cell, which is the channel outlet. A watershed is composed of all the cells with flow paths leading to this outlet. The start cell is identified and the flow directions are used to find the associated cells for each watershed. This collection of cells is given a watershed number. The watershed number of each cell is then compared with its neighbor cells to identify the watershed boundary cells.

6. Cell Characteristics: This component calculates θ, D and θ_D for each cell. Values of θ are estimated based on the neighborhood method (CERL, 1988). The neighborhood method considers the elevations of the eight neighboring cells and predicts the slope for the center cell. The D and θ_D estimates are based on the flow direction and network information previously described. To calculate D for a cell, the number of horizontal, vertical and diagonal flow directions between that cell and the first network cell to which it flows is calculated. A horizontal or vertical flow is then taken as the cell side length (ΔX), and a diagonal flow is $\Delta X^*\sqrt{2}$. The θ_D is the difference in the start cell and the network cell elevations divided by D.

2.1.2.3 Database Manager

The database manager is a tool for developing the soil and land-use data bases. It is also used to generate the files that contain, for each cell, information on soil characteristics, such as percent clay content, percent organic carbon, CN, λ, K, soil available phosphorus content, and soil pH.

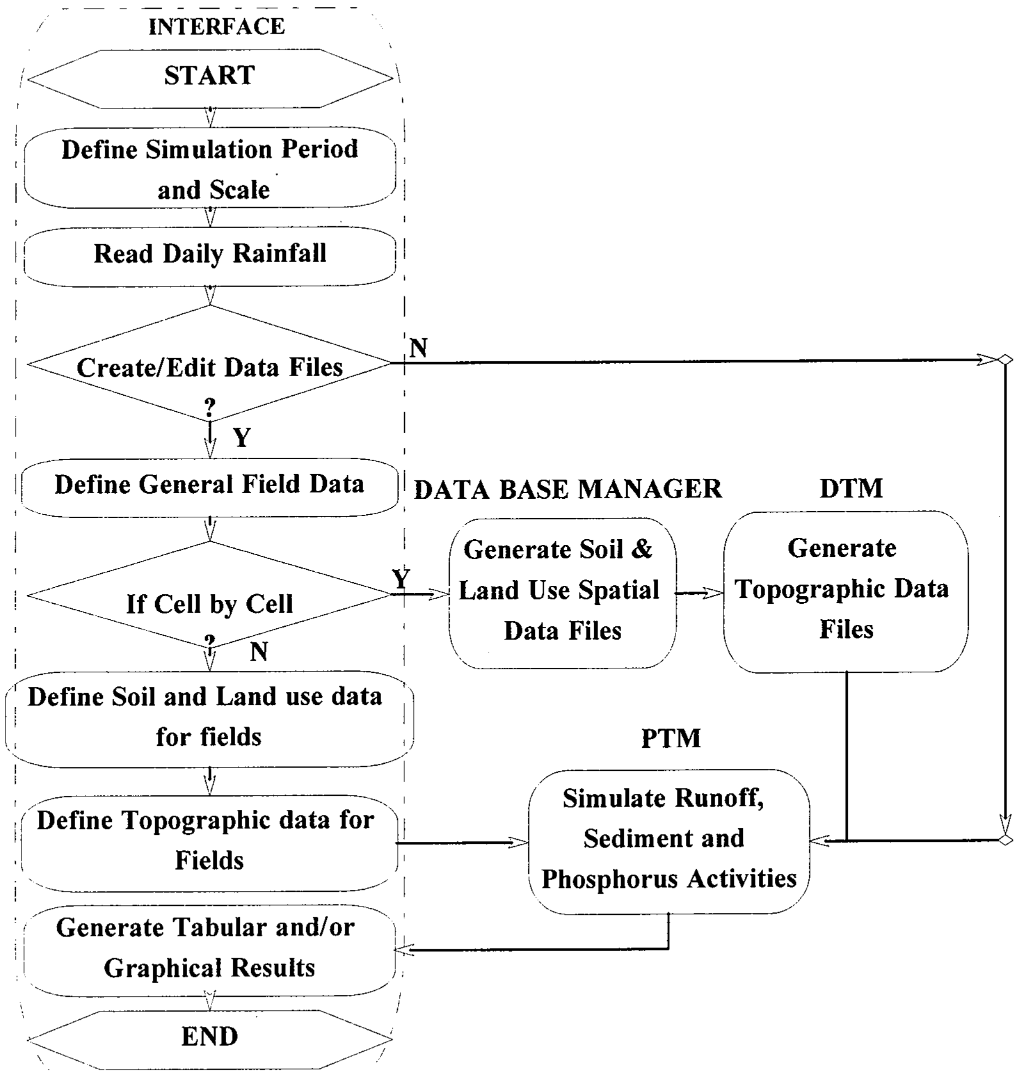


Figure 2.1 Schematic of SIMPLE modeling framework and interface flow chart.

2.2 DIGITAL SPATIAL DATA

Below is a description of the topography, soils and land use data used to model the sediment and phosphorus loading using SIMPLE. All model parameters utilized 30 m resolution data.

2.2.1 Topography

Using 7.5' USGS topographic maps, we created standard USGS digital elevation models (DEMs) for 25 USGS quadrangles: Blackgum, OK, Bunch, OK, Chance, OK, Cherokee City, AR-OK, Chewey, OK, Christie, OK, Colcord, OK, Cookson, OK, Gore, OK, Kansas, OK, Leach, OK, Moody's, OK, Park Hill, OK, Proctor, OK, Qualls, OK, Siloam Springs, AR-OK, Siloam Springs NW, OK, Stilwell East, OK-AR, Stilwell West, OK, Tailholt, OK, Tahlequah, OK, Thompson Corner, OK, Watts, OK-AR, Westville, OK-AR, Zeb, OK. The University of Arkansas scan and created four topographic maps: Bentonville South, AR, Centerton, AR, Gentry, AR, Rogers, AR. The digital elevation data were obtained from optically scanning mylar separates of the elevation contour lines for each 7.5' quadrangle. The separates were clear mylar which only contain the contour or elevation lines present on a standard topographic quadrangle. The topographic mylars were scanned on an ANATech 3640 Eagle optical scanner at 400 dpi.

The scanned raster images were imported into a public domain software package called LTPLUS. Next the raster images were edited, vectorized, and then labeled. During the editing process procedures were employed to identify potential errors in the scanned images and correct them. In addition, after the image was vectorized, the vectors were plotted to scale, overlaid on the original mylar, and compared visually for accuracy and completeness. A second operator independently verified the elevation label values of previously labeled vectors. A supervisor then performed a final evaluation of the completed data (vectorized and labeled image). As another check the DEM model was created, imported into a geographic information system software package, and viewed in two and three dimensions to identify potential errors. Statistics were also generated on the DEM to identify potential errors. All potential errors were verified and corrected.

In the final step the vector images were sent to the USGS. The USGS input each vector image into LT4X, a commercial image processing software package, and created a 30 m DEM, which was then entered into their national data base. Additional details on the use of LTPLUS is given in Appendix D.

There were seven missing DEM's for the quadrangles Elkins, AR, Fayetteville, AR, Lincoln, AR, Prairie Grove, AR, Sonora, AR, Springdale, AR, West Fork, AR. For the quadrangles we re-sampled the USGS 1:100,000 Fayetteville and Stilwell DEMs at 30 m and pasted the data into the missing quadrangles of the 1:24,000 DEM. Next we used a filter to smooth the gradient along the edges between the 1:24,000 and 1:100,000 DEMs. Although these 1:100,000 elevation estimates tended to underestimate field slopes, they still provided reasonable estimates given the lack of available data. The final composite DEM for the Upper Illinois River basin is given in Figure 2.2.

2.2.2 Soils

Soils data were digitized for the Oklahoma portion of the Upper Illinois River basin from NRCS County soil surveys. The University of Arkansas digitized the Arkansas portion of the basin. A 30 m resolution raster data layer was created from the vectorized images using GRASS. Additional details on the soils data base in given in the next section. The distribution of soils for the Upper Illinois River basin is given in Figure 2.3.

2.2.3 Land Use

The land use data layer for the Illinois River Basin was obtained from the U.S. Environmental Protection Agency, which was produced under contract by Lockheed Corporation. The maps were derived from photo-interpretation of 1:24,000 scale color infrared aerial film positives. The photography was flown August 30 through September 1, 1985.

The land use survey was completed utilizing a classification scheme adapted from Anderson et al. (1976). The Anderson scheme was modified to emphasize agricultural land uses. This classification scheme was further expanded during the digitization process to increase categories in the area of poultry, swine, and dairy operations.

After the aerial photography was interpreted in the original project, the information was transferred to clear, mylar overlays based upon USGS 7.5 minute (1:24000 scale) quadrangles, and digitized with an Altek graphic digitizer. Next, the features were labeled and the digitized quadrangle vector (polygon) data sets were merged into a single vector file so that edge-matching of polygons common to more than one quadrangle could be properly aligned. Finally, the vector land use data set for the Illinois River Basin was converted to raster format with a 30 meter resolution. The land use data layer utilized by SIMPLE, Figure 2.4, composited several categories into: 1) urban, 2) pasture and range, 3) transportation, communications, utilities, 4) crop, 5) orchards, groves, vineyards, 6) Nurseries, 7) forest, 8) poultry operations, 9) dairy, 10) hog operations, and 11) water.

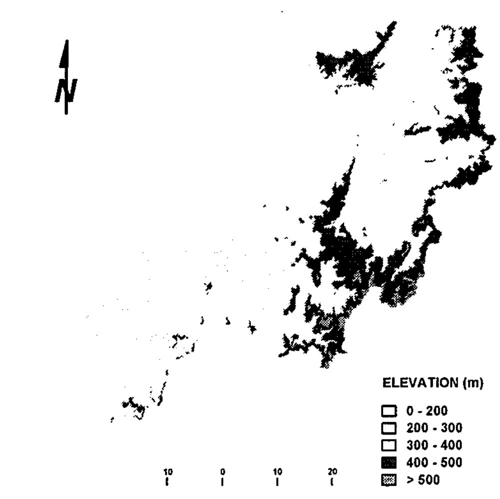


Figure 2.2 Topography of the Upper Illinois River basin using 1:24,000 DEM.

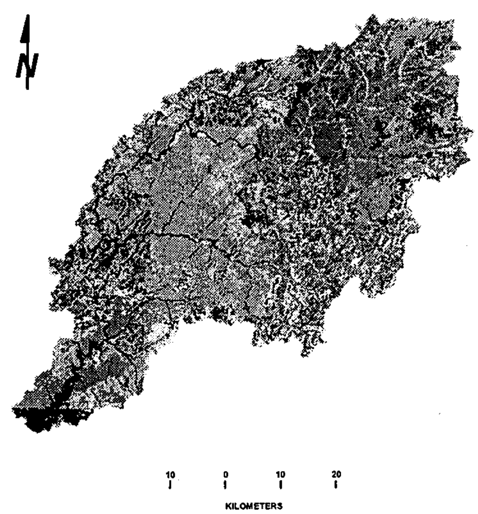


Figure 2.3 Soils distribution for the Upper Illinois River basin County level Soil Surveys.

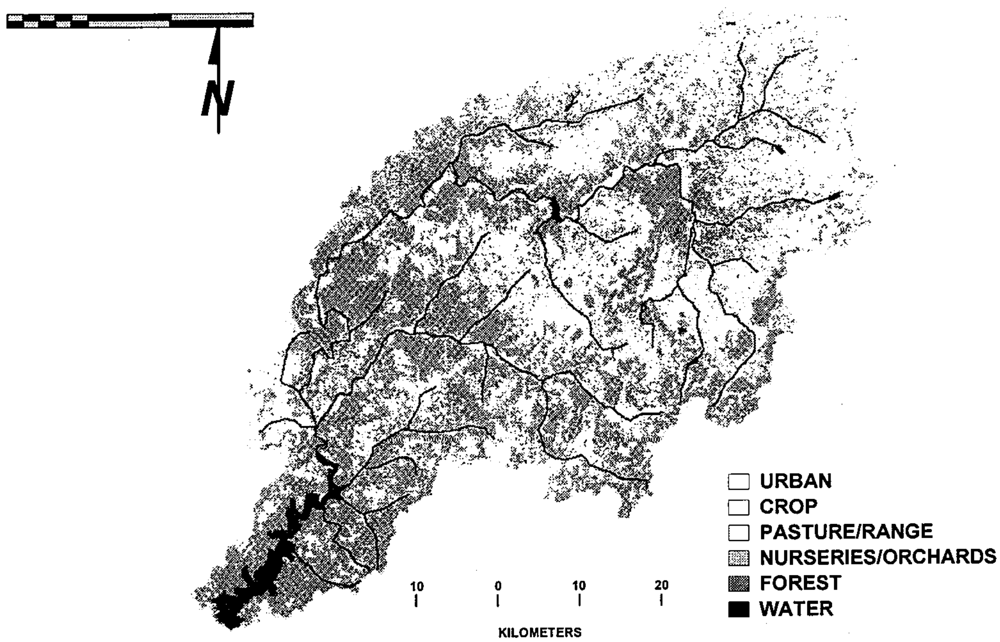


Figure 2.4 Land use distribution for the Upper Illinois River basin.

2.3 WATERSHED BOUNDARIES

The Upper Illinois River basin was divided into 15 sub-basins. The sub-basins and their UTM coordinates are: Osage (373720E 4003960N), Clear (379000E 3996460N), Fork (378955E 3996195N), Flint (344935E 4004175N), Baron (358060E 3974205N), Caney (328735E 3959345N), Benton (358285E 3999375N), River (345205E 4003455N), Bord (331315E 3981045N), Tyner (339985E 3980645N), West (339715E 3980535N), Bbaron (327085E 3968715N), Bilin (327055E 3969045N), Lakeup (327295E 3966795N), Lake (315355E 3940635N). The basin was divided into sub-basins to organize model results and to reduce the computer memory and hard disk requirements. The 15 sub-basins are shown in Figure 2.5.

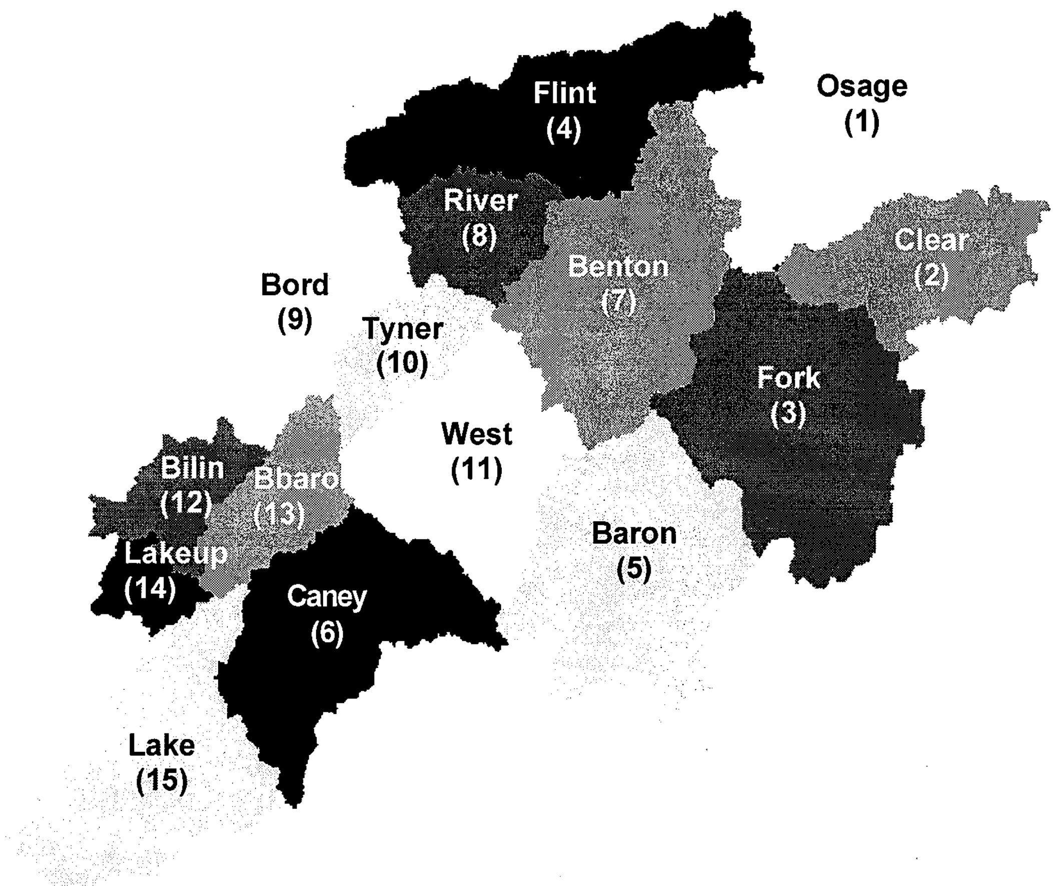


Figure 2.5. Subwatersheds identification for the Upper Illinois River Basin.

2.4 PARAMETER ESTIMATION

2.4.1 Topographic

SIMPLE requires cell/field slope, slope length, distance to stream and slope of distance to stream. The DTM used the 30 m DEM to estimate cell slope, and distance and slope to stream using procedures described by Sabbagh et al. (1994). However, the DEM was not detail enough to estimate slope length. Therefore, slope length was estimated using a modified procedure developed by the Oklahoma NRCS. Slope length (λ), as used in the USLE, was estimated based on county soil classification using two categories, upland soils and bottom land soils. All bottom land soils were assumed to have a slope length of 50 feet. The slope length for the upland soils was based on the soil mapping field slope as follows:

1. 0 to 1 percent slope - 600 foot slope length
2. 1 to 3 percent slope - 500 foot slope length
3. 3 to 5 percent slope - 400 foot slope length
4. 5 to 8 percent slope - 300 foot slope length
5. 8 to 12 percent slope - 200 foot slope length
6. > 12 percent slope - 50 foot slope length.

Table 2.1 presents field slope and slope length statistics for each watershed, and Table 2.2 gives the slope length for each soil type.

The next step was to define the stream network using the DTM. For each sub-basin we initially selected an arbitrary cut off value to define the stream network. By trial and error we changed the cut off value until the stream network visually approximated the 1:24,000 USGS blue line streams (continuous and intermittent flow steams). Next, distance to stream was estimated based on the flow path predicted by the DTM. The slope of this distance to stream was calculated as the ratio of the elevation drop to the stream and the distance to the stream. Distance to stream and slope of distance to stream is given in summarized in Table 2.1 for each watershed.

2.4.2 Soil and Management Parameters

Based on the Natural Resource Conservation Service (NRCS) County soils surveys, Table 2.3 gives the slope range and area for each soil type by county. Table 2.4 gives the USLE cover and management factors by land use based on USDA-SCS Handbook Number 537 (SCS, 1978). Hydrologic soil groups are given by land use in Table 2.5 based on NRCS County Soil Surveys.

2.4.4 Soil Phosphorus

Initial soil phosphorus is a very important input parameter for SIMPLE. We used the Mehlich III soil test values as an estimate of the available soil phosphorus that was input into SIMPLE. Soil test phosphorus is typically estimated for a field using a composite of 0 to 6 inch soil samples. It should be noted that SIMPLE requires the amount of available soil phosphorus in the upper one cm of the soil. However, based on validation and testing studies, we use the 0 to 6 inch composite Mehlich III soil test directly as the available soil phosphorus in the upper one cm of soil.

We had several data sources of soil phosphorus for the Upper Illinois River Basin. However, we only had detailed soil test phosphorus data for a few small watersheds within the basin. Therefore, we needed to develop a method to estimate soil phosphorus for the entire basin. First, we obtained all available soil test results from the Oklahoma State University Soil, Water, and Forage Analytical Laboratory. Data from Delaware County was from January 1993 through April 1995, Cherokee County data was from February 1993 through December 1994, and Adair County data were from January 1993 through May 1995. These data were identified by land use and county, but their specific location were unknown. Next, we obtained soil testing data from the Arkansas Soil and Water Conservation during the period December 1991 through April 1995. These data were only for pasture and were identified by watershed. A summary of the soil test phosphorus data for pasture is given in Table 2.6 and Figure 2.6 shows the counties and watershed numbers. It should be noted that we assumed these data were representative of soil test phosphorus levels. This assumption is untested, but was the best available.

Soil phosphorus was assigned to fields based on land use for all land uses except pasture. A summary of the assigned soil phosphorus levels is given in Table 2.7. The poultry, dairy, and hog houses were assumed to be land Use of rooftop, and thus had a zero soil phosphorus status. For pasture two physically-based methods for assigning initial soil phosphorus were developed. The first option was to fit probability density functions to the observed soil test phosphorus data by county for Oklahoma and by watershed for Arkansas. Next, Monte Carlo simulation methods could be used to randomly assign soil phosphorus to pastures by county or watershed. Although this method would be acceptable, a second alternative was employed.

The second option, which was used in this project, assigned initial soil phosphorus to pasture as a function of distance from poultry house(s) and the average soil test phosphorus by county or watershed. The rational for using distance from poultry house is that the owner of the poultry house(s) tend to apply litter on adjacent fields to minimize transportation costs. If the litter is applied to meet the nitrogen needs for forage production, then phosphorus will be over applied and will build up in the soil profile with time. High soil test phosphorus levels have been observed in the Battle Branch and Peacheater Creek watersheds under the recent USDA Hydrologic Unit Projects in Oklahoma. These data will be presented shortly to illustrate high soil test phosphorus levels next to poultry houses.

The first step in assigning initial soil phosphorus to pasture was to determine the number of poultry houses per county or watershed. The NRCS 1985 poultry house survey was utilized. It should be noted that there was a significant expansion of poultry houses in the Oklahoma potion of the basin from 1985 through 1992. However, in the absence of more recent data, the 1985 survey was used.

The NRCS survey identified sites that had from one to 11 poultry houses. The area of influence for each site was mapped using the GRASS 4.1 command *s.voronoi*, which mapped a relative area of influence for each site. Due to GRASS limitations from the large number of sites, *s.voronoi* was run for each county and watershed independently. Next, the distance from poultry house data layer was calculated for the entire basin simultaneously using the GRASS 4.1 command *r.cost*. An average number of poultry houses per site was calculated for each county or watershed (Table 2.8) and a weighing factor, W, was defined as:

$$W = \frac{\overline{P_{st}}\, H_n}{\overline{H_n}} \qquad 2.1$$

where $\overline{P_{st}}$ is the average soil test phosphorus for a county or watershed, H_n is the number of poultry houses per site, and $\overline{H_n}$ is the average number of poultry houses per site for a county or watershed. It should be noted that there are a number of weighting factors, W, one for each H_n.

The first approximation of the initial soil phosphorus for each 30 m cell, P_{soil1}, in the county or watershed was calculated using:

$$P_{soil1} = W\,\frac{D_{max} - D_H}{D_{max}} \qquad 2.2$$

where D_{max} is the distance in meters at which the soil phosphorus level reaches the native background level, and D_H is the distance from poultry house estimated from the r.cost function in meters. Next, the estimated average initial soil phosphorus, $\overline{P_{soil1}}$, for the county or watershed was calculated and an adjusted initial soil test phosphorus for each 30 m cell, P_{soil2}, was calculated using:

$$P_{soil2} = \frac{P_{soil1}\,\overline{P_{st}}}{\overline{P_{soil1}}} \qquad 2.3$$

To keep realistic initial soil phosphorus values, P_{soil2} was bounded between 15 and 1,200 lbs/ac. After bounding the data by 15 and 1,200, a new county or watershed average was calculated and the weighting function in equation 2.3 was employed a second time to ensure the average observed and predicted county of watershed soil phosphorus levels agreed. This process was repeated until the predicted and observed average county or watershed soil phosphorus were within five percent.

This methodology assigns a relatively high soil test phosphorus at a poultry house location, with phosphorus levels decreasing with distance from the poultry house. The rate at which the initial soil phosphorus decreased was governed by D_{max}. To estimate D_{max} the Peacheater Creek and Battle Branch watersheds were examined. For these watersheds detailed soil testing was conducted by the Oklahoma Cooperative Extension Service as part of two USDA Hydrologic Unit Area Projects. Figures 2.7 and 2.8 show the relationship between distance from poultry house and soil test phosphorus for Peacheater Creek and Battle Branch watersheds, respectively. Based on a linear regression and assuming a native soil phosphorus level of 15, D_{max} is 2,500 and 1,500 meters for the Peacheater Creek and Battle Branch watersheds, respectively.

The above methodology was initially applied to the Upper Illinois basin using a D_{max} of 2,500 meters. However, there was a significant portion of the estimated soil phosphorus levels that were in excess of 1,200 and some levels exceeded 3,000. By trial and error a D_{max} of 8000 meters was selected. The 8000 meter distance was selected based on visual comparison, and thus no statistical criteria were used. Using 8000 meters resulted in reasonable soil phosphorus levels compared to the observed soil test data. As indicated in Figures 2.7 and 2.8, there is considerable scatter in the data and a linear relationship may not necessarily be appropriate. However, the Peacheater Creek and Battle Branch watersheds are relatively small, 16,200 and 5,500 acres, respectively, and neighboring poultry houses outside the watershed are not taken into account. In addition, in the upper portion of the Peacheater Creek watershed there is a sizeable concentration of poultry houses that are owned by Hudson. The poultry litter from these houses is sold and none of the litter is applied to their adjacent pastures.

A comparison between the observed and predicted soil phosphorus levels for the Peacheater Creek and Battle Branch watersheds is shown in Figures 2.7 and 2.8, respectively. The slope of the predicted regression lines are much lower due to a D_{max} of 8000 meters. In addition, the grouping of predicted soil phosphorus parallel to the regression line is an artifact of the methodology. Throughout the watershed, soil phosphorus levels at each site of poultry house(s) is constant for a given number of poultry houses. Relative frequency comparisons for the Peacheater Creek and Battle Branch watersheds are given in Figures 2.9 and 2.10, respectively. As indicated in these figures, the agreement between observed and predicted soil phosphorus levels is poor.

Next, the methodology was applied to the entire basin. A comparison of the observed and predicted relative frequency distributions for each county/watershed is given in Figures 2.11 through 2.22. In general, the frequency distributions for the observed and predicted soil test values agreed. Figures 2.23 and 2.24 show the location of poultry houses and distance from poultry house for the Upper Illinois basin, respectively. Figure 2.25 shows the initial soil phosphorus for the basin used in SIMPLE.

The soil phosphorus data had units of lb P/ac. However, SIMPLE requires units of µg P/g soil. To convert lbs/ac to µg/g we assumed a dry soil bulk density of 1.5 g/cm^3 and a soil depth of 0.5 ft, thus yielding:

$$\frac{lbs\,P}{ac} * \frac{kg}{2.2\,lbs} * \frac{10^9\,\mu g}{kg} * \frac{ac}{43560\,ft^2} * \frac{1}{0.5\,ft} * \frac{(0.0328)^3\,ft^3}{cm^3} * \frac{cm^3}{1.5\,g\,soil} = 0.49\,\frac{\mu g\,P}{g\,soil} \qquad 2.4$$

or

$$\frac{lb}{ac} = 0.49\,\frac{\mu g}{g} \qquad 2.5$$

2.4.4 Fertilization

For the SIMPLE computer simulations, poultry litter was assumed to be applied to pasture/range land every April at a rate based on the number of poultry houses contained in the watershed. Each poultry house was assumed to hold 20,000 broilers and would produce 100 tons litter per year. This was based on 9.73 tons litter per 1000 ft^2 per year (Finley et al., 1994) and a 50 ft by 200 ft house. Next we assumed the litter contained 1.5 percent P, and thus each house produced 1400 kg P per year. The litter application rate to pasture for each of the watersheds is given in Table 2.9. It should be noted that we are neglecting commercial fertilizer, dairies, layers, pullets, and turkeys, and human water recreation impacts. However, relative to the broiler production these inputs were considered negligible.

For crop land we assumed an application of 20 kg P/ha/yr. For the remaining land uses we selected a P application rate that would keep the soil at approximately the same initial soil P level. We applied 0.3 kg P/ha/yr for urban areas, 0.06 kg P/ha/yr for transportation and utilities, 0.3 kg P/ha/yr for Orchards, Vineyards, and nurseries, and 0.03 kg P/ha/yr to forest land.

2.4.5 Precipitation

Daily precipitation as rainfall was required by SIMPLE. Weather stations located through the Illinois River Basin were located and the rainfall data compiled. As shown in Table 2.10, we used eight weather stations: Bentonville, Fayetteville, Kansas, Odell, Stilwell, Siloam Springs and Tahlequah. Figure 2.26 shows the location of weather stations and Table 2.10 indicates which weather station was used for each watershed.

Table 2.1. Topographic statistics by watershed for the Upper Illinois River Basin.

Watershed	Parameter	Slope (%)	Slope Length (meters)	Distance to Stream (meters)	Slope to Stream (%)
Osage	Mean	5.2	81	650	2.5
	Standard Deviation	4.5	47	463	2.2
	Minimum	0.0	15	0	0.0
	Maximum	30.8	306	2932	22.4
Clear	Mean	5.4	72	799	2.2
	Standard Deviation	4.7	40	576	1.9
	Minimum	0.0	15	0	0.0
	Maximum	30.0	183	3848	19.2
Fork	Mean	2.1	85	622	0.8
	Standard Deviation	5.1	34	896	2.6
	Minimum	0.0	15	0	0.0
	Maximum	42.0	183	5384	22.0
Flint	Mean	6.8	83	601	3.1
	Standard Deviation	5.6	44	423	2.5
	Minimum	0.0	15	0	0.0
	Maximum	32.5	183	2428	19.7
Baron	Mean	5.3	65	810	2.8
	Standard Deviation	6.2	42	488	3.8
	Minimum	0.0	10	0	0.0
	Maximum	72.0	189	3146	36.0
Caney	Mean	8.6	101	566	4.6
	Standard Deviation	6.0	39	415	3.2
	Minimum	0.0	15	0	0.0
	Maximum	33.0	189	2194	25.3
Benton	Mean	5.8	65	974	3.0
	Standard Deviation	6.0	45	423	3.6
	Minimum	0.0	15	0	0.0
	Maximum	50.0	201	2108	35.6
River	Mean	6.8	98	590	3.2
	Standard Deviation	6.4	42	414	2.9
	Minimum	0.0	15	0	0.0
	Maximum	26.6	189	1874	18.5
Bord	Mean	11.3	68	546	4.1
	Standard Deviation	7.6	39	413	3.7
	Minimum	0.0	15	0	0.0
	Maximum	34.7	183	1944	52.0

Table 2.1 (continued). Topographic statistics by watershed for the Upper Illinois River Basin.

Watershed	Parameter	Slope (%)	Slope Length (meters)	Distance to Stream (meters)	Slope to Steam (%)
Tyner	Mean	8.2	105	515	5.5
	Standard Deviation	6.6	30	397	4.1
	Minimum	0.0	15	0	0.0
	Maximum	40.2	184	2088	37.8
West	Mean	8.6	98	554	3.6
	Standard Deviation	6.2	35	432	2.7
	Minimum	0.0	15	0	0.0
	Maximum	33.0	189	2260	23.3
Bbaron	Mean	6.9	81	590	3.9
	Standard Deviation	6.1	45	496	3.6
	Minimum	0.0	15	0	0.0
	Maximum	29.2	183	3218	30.4
Bilin	Mean	7.3	75	648	3.0
	Standard Deviation	6.9	43	518	2.8
	Minimum	0.0	15	16	0.0
	Maximum	38.7	183	2897	16.2
Lakeup	Mean	6.3	97	629	1.9
	Standard Deviation	5.0	43	523	2.1
	Minimum	0.0	15	15	0.0
	Maximum	23.6	183	2035	10.8
Lake	Mean	8.5	95	684	5.0
	Standard Deviation	6.0	47	497	5.5
	Minimum	0.0	0	0	0.0
	Maximum	40.4	168	3352	117.6

Table 2.2. Soil characteristics for the Upper Illinois River Basin (USLE K factor in English units).

Soil Number	USLE K	Hydrologic Soil Group	PH	Organic Carbon (%)	Clay (%)	Bulk Density (g/cm^3)	Slope Length (m)
1	0.28	B	6.10	0.44	14	1.45	122
2	0.28	B	5.25	0.44	14	1.45	61
3	0.28	B	5.25	0.44	14	1.45	61
4	0.37	C	5.25	0.44	25	1.45	152
5	0.43	B	5.00	0.74	25	1.43	152
6	0.43	B	5.00	0.74	25	1.43	152
7	0.37	B	5.00	1.18	25	1.39	189
8	0.37	B	5.00	1.18	25	1.39	152
9	0.37	B	5.00	1.18	25	1.39	152
10	0.37	B	5.40	1.18	25	1.39	122
11	0.01	B	7.00	0.01	0.01	1.00	15
12	0.1	C	5.80	0.74	13	1.51	152
13	0.19	C	5.00	0.85	17	1.50	152
14	0.28	B	6.70	2.65	25	1.28	15
15	0.28	B	6.70	2.65	24	1.34	15
16	0.43	C	5.80	0.01	18	1.51	189
17	0.43	C	5.50	1.47	18	1.39	152
18	0.28	B	4.55	1.03	10	1.52	152
19	0.28	B	4.55	1.03	10	1.52	122
20	0.28	B	4.55	1.03	19	1.48	122
21	0.28	B	4.55	1.03	19	1.48	122
22	0.28	D	6.20	1.47	37	1.29	15
23	0.49	D	5.80	0.44	25	1.45	183
24	0.32	D	7.25	0.01	33	1.54	152
25	0.37	C	6.45	1.18	33	1.34	183
26	0.37	C	6.45	0.10	33	1.34	152
27	0.37	C	6.45	1.18	33	1.34	122
28	0.37	C	6.45	1.18	33	1.34	122
29	0.43	D	5.00	2.06	18	1.34	15
30	0.49	C	5.55	0.44	25	1.45	183
82	0.01	D	7.00	0.01	0.01	1.00	152
87	0.01	D	7.00	0.01	0.01	1.00	152
88	0.01	D	7.00	0.01	0.01	1.00	152
98	0.01	B	7.00	0.01	0.01	1.00	152
102	0.28	B	5.25	1.74	18	1.37	152
103	0.28	B	5.50	1.74	18	1.37	152
104	0.33	B	5.25	1.18	14	1.42	122
105	0.43	B	5.50	1.18	12	1.43	152
108	0.28	B	4.80	0.74	12	1.46	122
109	0.28	B	4.80	0.74	25	1.43	61
110	0.28	B	4.80	0.74	25	1.43	30
114	0.37	D	6.05	1.18	25	1.39	122
116	0.37	A	6.45	0.88	25	1.42	15
117	0.1	C	5.80	0.74	10	1.54	122
118	0.19	B	5.00	0.88	10	1.53	152
119	0.43	C	5.80	0.01	18	1.51	183
120	0.28	B	4.55	1.03	10	1.52	137

Table 2.2 (continued). Soil characteristics for the Upper Illinois River Basin (USLE K factor in English units).

Soil Number	USLE K	Hydrologic Soil Group	PH	Organic Carbon (%)	Clay (%)	Bulk Density (g/cm^3)	Slope Length (m)
121	0.37	B	5.00	0.59	12	1.48	152
122	0.37	B	6.05	1.18	18	1.41	183
123	0.37	B	6.05	1.18	18	1.41	152
124	0.37	B	6.05	1.18	18	1.41	91
128	0.43	C	6.45	1.18	33	1.38	152
129	0.43	C	6.45	1.18	33	1.38	122
130	0.28	D	6.45	1.47	45	1.31	15
132	0.01	D	7.00	0.01	0.01	1.00	152
133	0.37	B	6.45	0.74	12	1.46	15
134	0.37	B	6.45	0.74	12	1.46	15
135	0.37	B	6.45	0.74	15	1.54	15
136	0.37	B	6.45	0.74	15	1.54	107
137	0.32	B	6.45	1.76	25	1.35	15
138	0.3	B	6.45	1.76	24	1.35	15
139	0.49	D	5.00	1.18	12	1.43	183
140	0.37	C	6.45	1.18	33	1.34	137
141	0.49	C	5.55	0.44	25	1.45	183
142	0.32	D	8.15	1.18	24	1.46	107
143	0.32	D	8.15	1.18	24	1.46	30
206	0.23	C	5.00	1.00	13	1.51	15
210	0.19	D	5.50	0.88	11	1.53	122
211	0.19	D	5.50	0.88	11	1.53	90
212	0.37	C	4.80	1.10	11	1.48	122
221	0.43	B	5.00	1.03	15	1.43	152
222	0.43	B	5.00	1.03	18	1.43	122
223	0.43	B	5.00	1.03	18	1.43	122
229	0.37	B	5.00	0.10	22	1.43	15
234	0.32	D	7.25	0.01	33	1.54	15
236	0.49	D	4.75	1.00	15	1.44	183
238	0.49	C	5.00	1.18	12	1.43	152
241	0.37	C	6.45	1.18	33	1.34	152
320	0.28	B	5.50	1.76	18	1.38	122
321	0.28	B	5.50	1.76	18	1.38	61
322	0.28	B	5.50	1.76	18	1.38	30
323	0.28	B	5.50	1.76	18	1.38	15
335	0.37	C	5.25	0.88	15	1.43	107
336	0.37	C	5.25	0.88	15	1.43	61
345	0.43	B	5.50	1.18	8	1.45	152
346	0.43	C	5.50	1.18	12	1.43	400
348	0.43	B	5.50	1.18	8	1.45	122
349	0.43	B	5.50	1.18	8	1.45	122
352	0.43	B	6.20	0.74	18	1.47	152
356	0.28	B	4.80	0.74	25	1.44	30
357	0.28	B	4.80	0.74	25	1.44	15
374	0.37	A	6.45	0.88	8	1.51	15
381	0.28	B	6.70	1.76	25	1.36	15

Table 2.2 (continued). Soil characteristics for the Upper Illinois River Basin (USLE K factor in English units).

Soil Number	USLE K	Hydrologic Soil Group	PH	Organic Carbon (%)	Clay (%)	Bulk Density (g/cm^3)	Slope Length (m)
401	0.37	B	6.05	1.76	14	1.38	15
402	0.2	B	7.00	0.01	8	1.27	122
404	0.37	B	6.05	1.76	14	1.38	15
409	0.43	B	5.80	0.01	6	1.53	152
410	0.43	B	5.80	XX	6	1.53	122
411	0.43	B	5.50	0.88	12	1.47	152
413	0.43	C	5.50	0.88	12	1.47	152
414	0.32	C	4.55	1.18	18	1.43	183
415	0.37	C	4.55	1.18	18	1.43	152
423	0.49	C	6.20	1.18	35	1.34	152
442	0.33	B	6.05	1.18	18	1.43	152
443	0.32	B	5.00	1.18	18	1.43	107
444	0.32	B	5.00	1.18	18	1.43	61
445	0.43	C	5.00	1.18	18	1.43	107
453	0.28	B	5.50	1.18	18	1.43	61
454	0.28	B	5.50	1.18	18	1.43	30
455	0.28	B	5.50	1.16	18	1.43	15
464	0.32	B	5.90	1.76	25	1.36	152
465	0.32	B	5.25	1.76	25	1.36	122
466	0.32	B	5.25	1.74	18	1.41	107
467	0.37	B	5.25	1.16	12	1.45	152
469	0.37	B	5.25	1.18	12	1.45	107
471	0.43	B	5.25	1.03	18	1.44	152
472	0.43	B	5.00	1.03	18	1.44	107
473	0.43	B	5.00	1.03	18	1.44	107
474	1.43	B	5.00	1.03	18	1.44	61
489	0.37	B	6.70	1.18	18	1.49	15
493	0.37	B	6.70	1.18	18	1.43	15
494	0.37	B	6.70	1.18	18	1.43	15
497	0.01	D	1.00	0.01	0.01	2.65	152
501	0.32	B	5.80	1.18	17	1.41	15
506	0.37	B	6.95	2.65	25	1.29	15
507	0.32	C	7.25	0.01	25	1.51	152
515	0.37	D	6.45	1.18	42	1.31	183
516	0.37	D	6.45	1.18	42	1.31	152
517	0.37	D	6.45	1.18	42	1.31	107
518	0.37	D	6.45	1.18	42	1.31	76
519	0.37	D	6.45	1.18	42	1.31	30
520	0.37	D	6.45	1.76	33	1.29	107
521	0.37	D	6.45	1.76	33	1.29	61
522	0.37	D	6.45	1.47	37	1.30	152
523	0.49	C	5.55	0.44	12	1.47	183
524	0.49	D	5.55	0.44	12	1.47	152
525	0.49	C	5.55	0.44	12	1.47	152
526	0.37	B	5.00	0.01	13	1.53	107
533	0.28	A	5.80	0.74	8	1.48	107
534	0.28	A	5.80	0.74	8	1.48	61

Table 2.2 (continued). Soil characteristics for the Upper Illinois River Basin (USLE K factor in English units).

Soil Number	USLE K	Hydrologic Soil Group	PH	Organic Carbon (%)	Clay (%)	Bulk Density (g/cm^3)	Slope Length (m)
601	0.24	A	4.55	1.47	19	1.46	107
602	0.24	A	4.55	1.47	19	1.46	91
603	0.24	A	4.55	1.47	19	1.46	61
604	0.24	A	4.55	1.47	19	1.46	61
605	0.24	A	4.55	1.47	19	1.46	15
611	0.28	A	5.00	1.03	12	1.50	107
612	0.28	A	5.00	1.03	12	1.50	61
613	0.28	A	5.00	1.03	12	1.50	31
614	0.28	A	5.00	1.03	19	1.50	15
615	0.28	A	5.00	1.03	19	1.50	61
622	0.19	A	5.50	0.88	15	1.53	15
627	0.37	A	5.00	1.18	19	1.49	152
628	0.37	A	5.00	1.18	19	1.49	91
629	0.37	A	5.00	1.18	19	1.49	91
630	0.2	C	6.05	0.59	13	1.55	350
638	0.43	C	5.90	1.18	13	1.43	152
639	0.43	C	5.90	1.18	13	1.43	152
640	0.32	B	6.45	1.18	16	1.51	15
645	0.37	A	6.45	0.88	12	1.47	15
646	0.37	A	6.45	0.88	19	1.51	15
655	0.32	C	4.55	1.18	19	1.49	91
656	0.32	C	4.55	1.18	19	1.49	91
657	0.32	C	4.55	1.18	19	1.49	91
658	0.32	C	4.55	1.88	19	1.49	61
659	0.32	C	4.55	1.18	19	1.49	61
662	0.32	C	4.55	1.76	16	1.47	91
664	0.32	C	4.55	1.76	16	1.47	30
668	0.28	C	4.55	1.61	19	1.45	61
669	0.28	C	4.55	1.61	19	1.45	61
684	0.24	B	6.05	1.18	16	1.51	91
685	0.24	B	6.05	1.18	16	1.51	61
686	0.24	B	6.10	1.18	16	1.51	31
687	0.24	B	6.10	1.18	16	1.51	15
688	0.17	B	5.90	1.00	13	1.53	10
689	0.15	C	5.50	0.88	10	1.55	152
690	0.15	C	5.50	0.88	10	1.55	61
691	0.15	C	5.50	0.88	11	1.55	61
708	0.28	B	4.55	1.03	4	1.52	107
712	0.33	B	4.55	1.03	19	1.50	152
714	0.28	B	4.55	1.03	19	1.50	91
716	0.28	B	4.55	1.03	13	1.51	91
717	0.28	B	4.55	1.03	13	1.51	61
724	0.28	C	5.25	0.74	18	1.47	91
725	0.2	B	5.25	1.18	6	1.54	30
726	0.2	B	5.25	1.18	6	1.54	91
727	0.2	B	5.25	1.18	6	1.54	15

Table 2.2 (continued). Soil characteristics for the Upper Illinois River Basin (USLE K factor in English units).

Soil Number	USLE K	Hydrologic Soil Group	PH	Organic Carbon (%)	Clay (%)	Bulk Density (g/cm^3)	Slope Length (m)
791	0.49	C	6.05	1.76	25	1.36	152
794	0.49	C	6.05	1.76	25	1.36	152
795	0.37	B	4.55	1.03	10	1.54	152
796	0.37	B	4.55	1.03	10	1.54	91
834	0.32	C	4.55	1.76	16	1.47	15
852	0.25	C	4.90	1.10	13	1.53	30
882	0.28	B	4.55	1.03	4	1.52	15
917	0.17	D	5.25	1.18	10	1.53	90
931	0.2	B	5.00	1.03	16	1.53	120
938	0.26	B	4.75	1.10	16	1.52	30
939	0.26	B	4.75	1.10	16	1.52	15
999	0.01	D	7.00	0.01	0	1.00	152

Table 2.3. Soils data base.

County	Soil Number	Soil Name/Classification	Slope Range (%)	Area (ha)	Watershed Coverage (%)
Adair, OK	1	Bodine very cherty silt loam	1-8	21,753	5.17
	2	Bodine stony silt loam	5-15	5279	1.25
	3	Bodine stony silt loam	steep	30,284	7.20
	4	Craig cherty silt loam	1-5	417	0.10
	5	Dickson silt loam	1-3	5339	1.27
	6	Dickson cherty silt loam	0-3	8370	1.99
	7	Etowah silt loam	0-1	601	0.14
	8	Etowah silt loam	1-3	2215	0.53
	9	Etowah gravelly silt loam	1-3	4038	0.96
	10	Etowah and Greendale soils	3-8	6376	1.52
	11	Gravelly alluvial land	---	3245	0.77
	12	Hector complex	---	6397	1.52
	13	Hector-Linker fine sandy loams	1-5	1815	0.43
	14	Huntington silt loam	---	400	0.10
	15	Huntington gravelly loam	---	993	0.24
	16	Jay silt loam	0-2	1258	0.30
	17	Lawrence silt loam	---	231	0.05
	18	Linker fine sandy loam	1-5	556	0.13
	19	Linker fine sandy loam	3-5	109	0.03
	20	Linker loam	3-5	473	0.11
	21	Linker loam	3-5	117	0.03
	22	sage clay loam	---	178	0.04
	23	Parsons silt loam	0-1	203	0.05
	24	Sogn soils	---	562	0.13
	25	Summit silty clay loam	0-1	254	0.06
	26	Summit silty clay loam	1-3	379	0.09
	27	Summit silty clay loam	3-5	163	0.04
	28	Summit silty clay loam	3-5	63	0.02
	29	Taft silt loam	---	600	0.14
	30	Taloka silt loam	0-1	81	0.02
	82	Borrow Pits	---	30	0.01
	83	Gravel Pits	---	34	0.01
	87	Pits Quarries	---	6	0.00
	88	Quarries	---	36	0.01
	98	water	---	5730	1.36
Cherokee & Delaware, OK	102	Baxter silt loam	1-3	1069	0.25
	103	Baxter cherty silt loam	1-3	1070	0.25
	104	Baxter-Locust complex	3-5	1317	0.31
	105	Captina silt loam	1-3	2504	0.60
	108	Clarksville very cherty silt loam	1-8	10941	2.60
	109	Clarksville stony silt loam	5-20	6575	1.56
	110	Clarksville stony silt loam	20-50	30516	7.25
	111	Collinsville fine sandy loam	2-5	14	0.00
	114	Eldorado silt loam	3-5	625	0.15
	115	Eldorado soils	3-12	267	0.06
	116	Elsah soils	---	4451	1.06

Table 2.3 (continued). Soils data base.

County	Soil Number	Soil Name/Classification	Slope Range (%)	Area (ha)	Watershed Coverage (%)
Cherokee & Delaware, OK	117	Hector fine sandy loam	2-5	2072	0.49
	118	Hector-Linker association hilly	---	12681	3.01
	119	Jay silt loam	0-2	611	0.15
	120	Linker fine sandy loam	2-5	664	0.16
	121	Locust cherty silt loam	1-3	3539	0.84
	122	Newtonia silt loam	0-1	58	0.01
	123	Newtonia silt loam	1-3	827	0.20
	124	Newtonia silt loam3-5	---	338	0.08
	125	Newtonia silt loam	2-5	100	0.02
	127	Okemah silty clay loam	0-1	366	0.09
	128	Okemah silty clay loam	1-3	708	0.17
	129	Okemah silty clay loam	3-5	162	0.04
	130	Osage clay	---	377	0.09
	132	Rough stony land	---	2698	0.64
	133	Sallisaw silt loam	0-1	383	0.09
	134	Sallisaw silt loam	1-3	1549	0.37
	135	Sallisaw gravelly silt loam	1-3	2149	0.51
	136	Sallisaw gravelly silt loam	3-8	5125	1.22
	137	Staser silt loam	---	1106	0.26
	138	Staser gravelly loam	---	2748	0.65
	139	Stigler silt loam	0-1	925	0.22
	140	Summit silty clay loam	2-5	317	0.08
	141	Taloka silt loam	0-1	323	0.08
	142	Talpa-Rock outcrop complex	2-8	1294	0.31
	143	Talpa-Rock outcrop complex	15-50	4771	1.13
Sequoyah, OK	203	Cleora fine sandy loam	---	21	0.01
	206	Hector-Linker-Enders complex	5-40	7110	1.69
	210	Linker-Hector complex	2-5	1118	0.27
	211	Linker-Hector complex	5-8	64	0.02
	212	Linker and Stigler soils	2-8	50	0.01
	216	Mason silt loam	---	269	0.06
	221	Pickwick loam	1-3	307	0.07
	222	Pickwick loam	3-5	414	0.10
	223	Pickwick loam	2-5	56	0.01
	224	Razort fine sandy loam	---	62	0.01
	227	Rosebloom silt loam	---	21	0.01
	229	Rosebloom and Ennis soils broken	---	325	0.08
	230	Sallisaw complex	8-30	14	0.00
	231	Sallisaw loam	1-3	24	0.01
	232	Sallisaw loam	3-5	59	0.01
	233	Sallisaw loam	2-5	34	0.01
	234	Sogn complex	10-25	483	0.11
	236	Stigler-Wrightsville silt loams	0-1	104	0.02
	238	Stigler silt loam	1-3	414	0.10
	239	Stigler silt loam	2-5	7.38	0.00
	241	Summit silty clay loam	1-3	56	0.01
	242	Summit silty clay loam	3-5	140	0.03

Table 2.3 (continued). Soils data base.

County	Soil Number	Soil Name/Classification	Slope Range (%)	Area (ha)	Watershed Coverage (%)
Washington & Benton, AR	320	Baxter cherty silt loam	3-8	118	0.03
	321	Baxter cherty silt loam	8-12	298	0.07
	322	Baxter cherty silt loam	12-20	240	0.06
	323	Baxter cherty silt loam	20-45	1914	0.45
	335	Britwater gravelly silt loam	3-8	1320	0.31
	336	Britwater gravelly silt loam	8-12	13	0.00
	345	Captina silt loam	1-3	17124	4.07
	348	Captina silt loam	3-6	1534	0.36
	349	Captina silt loam	3-6	5587	1.33
	352	Craytown silt loam		204	0.05
	356	Clarksville cherty silt loam	12-50	11213	2.67
	357	Clarksville cherty silt loam	12-60	10874	2.58
	374	Elsah soils		1988	0.47
	381	Fatima silt loam occasionally flooded		559.17	0.13
	401	Guin cherty silt loam	3-8	1143	0.27
	402	Healing silt loam		473.22	0.11
	404	Healing silt loam occasionally flooded		1949	0.46
	409	Jay silt loam	1-3	4212	1.00
	410	Jay silt loam	3-8	951	0.23
	411	Johnsburg silt loam		3553	0.84
	413	Johnsburg complex mounded		260	0.06
	414	Leaf silt loam		1163	0.28
	415	Leaf complex mounded		573	0.14
	423	Mayes silty clay loam		267	0.06
	442	Newtonia silt loam	1-3	374	0.09
	443	Nixa cherty silt loam	3-8	22615	5.38
	444	Nixa cherty silt loam	8-12	5729	1.36
	44	5Nixa very cherty silt loam	3-8	2.88	0.00
	453	Noark very cherty silt loam	8-12	370	0.09
	454	Noark very cherty silt loam	12-20	990	0.24
	455	Noark very cherty silt loam	20-45	1524	0.36
	464	Pembroke silt loam	1-3	762	0.18
	465	Pembroke silt loam	3-6	1065	0.25
	466	Pembroke gravelly silt loam	3-8	613	0.15
	467	Peridge silt loam	1-3	2013	0.48
	469	Peridge silt loam	3-8	1646	0.39
	471	Pickwick silt loam	1-3	844	0.20
	472	Pickwick silt loam	3-8	5529	1.31
	473	Pickwick gravelly loam	3-8	150	0.04
	474	Pickwick gravelly loam	8-12	68	0.02
	489	Razort loam		679	0.16
	493	Razort silt loam occasionally flooded		1726	0.41
	494	Razort gravelly silt loam occasionally flooded		2182	0.52
	497	Rock land		191	0.05
	501	Secesh gravelly silt loam occasionally flooded		4506	1.07

Table 2.3 (continued). Soils data base.

County	Soil Number	Soil Name/Classification	Slope Range (%)	Area (ha)	Watershed Coverage (%)
Washington &	506	Sloan silt loam		1962	0.47
Benton, AR	507	Sogn rocky silt loam		573	0.14
	515	Summit silty clay	0-1	1647	0.39
	516	Summit silty clay	1-3	325	0.08
	517	Summit silty clay	3-8	416	0.10
	518	Summit silty clay	3-15	21	0.01
	519	Summit silty clay	8-12	77	0.02
	520	Summit stony silty clay	3-12	335	0.08
	521	Summit stony silty clay	12-25	45	0.01
	522	Summit complex mounded		92	0.02
	523	Taloka silt loam	0-1	3651	0.87
	524	Taloka silt loam	1-3	697	0.17
	525	Taloka complex mounded		531	0.13
	526	Tonti cherty silt loam	3-8	7977	1.90
	533	Waben very cherty silt loam	3-8	781	0.19
	534	Waben very cherty silt loam	8-12	62	0.01
	601	Allegheny gravelly loam	3-8	138	0.03
	602	Allegheny gravelly loam	3-8	201	0.05
	60	3Allegheny gravelly loam	8-12	87	0.02
	604	Allegheny stony loam	8-12	235	0.06
	605	Allegheny stony loam	12-40	272	0.06
	611	Allen loam	3-8	238	0.06
	612	Allen loam	8-12	220	0.05
	613	Allen loam	12-20	127	0.03
	614	Allen stony loam	12-35	132	0.03
	615	Allen soils	8-20	36	0.01
	622	Allen-Hector complex	20-40	167	0.04
	627	Apison loam	1-3	113	0.03
	628	Apison loam	3-8	1125	0.27
	629	Apison gravelly loam	3-8	203	0.05
	630	Cane loam	3-8	135	0.03
	638	Cherokee silt loam		2031	0.48
	639	Cherokee complex mounded		244	0.06
	640	Cleora fine sandy loam		1893	0.45
	645	Elsah gravelly soils		1244	0.30
	646	Elsah cobbly soils		890	0.21
	655	Enders gravelly loam	3-8	106	0.03
	656	Enders gravelly loam	3-8	640	0.15
	657	Enders gravelly loam	3-12	398	0.09
	658	Enders gravelly loam	8-12	242	0.06
	659	Enders gravelly loam	8-12	204	0.05
	662	Enders stony loam	3-12	2531	0.60
	664	Enders stony loam	12-30	132	0.03
	668	Enders-Allegheny Complex	8-20	8062	1.92
	669	Enders-Allegheny Complex	20-40	10162	2.42
	684	Fayetteville fine sandy loam	3-8	1814	0.43

Table 2.3 (continued). Soils data base.

County	Soil Number	Soil Name/Classification	Slope Range (%)	Area (ha)	Watershed Coverage (%)
Washington & Benton, AR	685	Fayetteville fine sandy loam	8-12	471	0.11
	686	Fayetteville fine sandy loam	12-20	178	0.04
	687	Fayetteville stony fine sandy loam	12-35	340	0.08
	688	Fayetteville-Hector complex	20-40	782	0.19
	689	Hector-Mountainburg gravelly fine sandy loams	3-8	1136	0.27
	690	Hector-Mountainburg gravelly fine sandy loams	8-12	285	0.07
	691	Hector-Mountainburg stony fine sandy loams	3-40	6533	1.55
	708	Linker fine sandy loam	3-8	877	0.21
	712	Linker loam	1-3	284	0.07
	714	Linker loam	3-8	2950	0.70
	716	Linker gravelly loam	3-8	851	0.20
	717	Linker gravelly loam	8-12	47	0.01
	724	Montevallo soils	3-12	308	0.07
	725	Montevallo soils	12-25	37	0.01
	726	Mountainburg stony sandy loam	3-12	29	0.01
	727	Mountainburg stony sandy loam	12-40	16	0.00
	791	Samba silt loam		63	0.15
	794	Samba complex mounded		118	0.03
	795	Savannah fine sandy loam	1-3	656	0.16
	796	Savannah fine sandy loam	3-8	3893	0.93
Crawford, AR	834	Enders stony fine sandy loam	12-45	46	0.01
	852	Enders-Mountainburg Association rolling		70	0.02
	882	Linker fine sandy loam	3-8	22	0.01
	917	Mountainburg stony fine sandy loam	3-12	3	0.00
	931	Nella gravelly fine sandy loam	3-8	7	0.00
	938	Nella-Enders Association rolling		68	0.02
	939	Nella-Enders Association steep		204	0.05
	999			490	0.12

Table 2.4. USLE C factors.

Land Use	Julian Day	USLE C Factor
Urban	---	0.003
Transportation, Communications, Utilities	---	0.003
Crop	1	0.40
	70	0.31
	90	0.24
	120	0.13
	150	0.10
	180	0.08
	210	0.08
	211	0.40
	300	0.20
	365	0.40
Pasture/Range	---	0.003
Orchards, Groves, Vineyards	---	0.30
Nurseries	---	0.30
Forest	---	0.003
Poultry Operations	---	0
Dairy	---	0
Hog Operations	---	0
Water	---	0

Table 2.5. Hydrologic soils group and curve number.

Hydrologic Soil Group	Land Use Number	Land Use	Curve Number
A	1	Urban	71
B			78
C			84
D			86
A	2	Transportation	72
B			82
C			87
D			89
A	3	Crop	63
B			75
C			83
D			87
A	4	Pasture/Range	49
B			69
C			79
D			84
A	5	Orchards	41
B			55
C			69
D			71
A	6	Nurseries	69
B			75
C			82
D			86
A	7	Forest	36
B			60
C			73
D			79
A	8	Poultry Operations	100
B			100
C			100
D			100
A	9	Dairy	100
B			100
C			100
D			100
A	10	Hog Operations	100
B			100
C			100
D			100
A	11	Water	100
B			100
C			100
D			100

Table 2.6. Observed soil test phosphorus statistics for pasture in the Upper Illinois River Basin from 1992 to 1995.

County or Watershed Number	State	Number of Samples	Mean (lb/ac)	Median (lb/ac)	Standard Deviation (lb/ac)	Minimum (lb/ac)	Maximum (lb/ac)
Delaware	OK	370	93	56	80	7	520
Adair	OK	214	159	64	188	9	1224
Cherokee	OK	109	52	41	35	9	167
Sequoyah	OK	0	-	-	-	-	-
010	AR	25	341	226	194	77	717
020	AR	37	297	203	231	45	999
030	AR	167	301	245	194	45	999
040	AR	25	239	127	233	54	883
050	AR	3	295[1]	-	-	-	-
060	AR	26	358	337	176	53	785
070	AR	54	227	161	194	31	999
080	AR	27	261	254	148	17	656
081	AR	0	242[2]	-	-	-	-

[1]Approximated as the average of watersheds 030, 060 and 070.
[2]Approximated as the average of watersheds 040, 070 and 080.

Table 2.7. Initial soil test phosphorus by land use for the Upper Illinois River Basin.

Land Use	Soil Test Phosphorus (lb/ac)	Area (ha)	Area (%)
Urban	60	14,985	3.5
Transportation, Communication, and Utilities	15	1,227	0.3
Crop	60	4,140	1.0
Pasture and Range	Variable[1]	211,518	49.
Orchards, Groves, Vineyards	60	1,425	0.3
Nurseries	60	148	0.03
Forest	10	186,205	44.
Poultry, Dairy, and Hog Houses	0	1,653	0.4
Water	0	6,912	1.6

[1]Defined as a function of distance from poultry house.

Table 2.8. Poultry house and area statistics for the Upper Illinois River Basin for 1985.

County or Watershed Number	State	Houses	Sites	Houses Per Site	Area (ha)
Delaware	OK	64	34	1.88	20,070
Adair	OK	313	158	1.98	102,960
Cherokee	OK	73	34	2.15	109,300
Sequoyah	OK	0	0	0	?
010	AR	214	102	2.10	24,230
020	AR	227	105	2.16	20,440
030	AR	751	306	2.45	58,430
040	AR	268	126	2.13	18,840
050	AR	95	37	2.57	16,030
060	AR	200	91	2.20	17,140
070	AR	111	49	2.27	12,390
080	AR	260	143	1.82	21,910
081	AR	141	61	2.31	5,710

Table 2.9. Number of poultry houses, pasture applied phosphorus and pasture area by watershed.

Watershed Number	Watershed Name	Number of Poultry Houses	Pasture Applied Litter (kg/ha)	Pasture Area (ha)
1	Osage	739	1,804	38,244
2	Clear	219	1,794	11,392
3	Fork	462	1,697	25,411
4	Flint	280	1,350	19,362
5	Baron	412	2,026	18,976
6	Caney	48	374	11,988
7	Benton	286	1,176	22,702
8	River	17	280	5,669
9	Bord	40	376	10,172
10	Tyner	17	294	5,395
11	West	143	958	14,910
12	Bbaron	24	179	5,077
13	Bilin	5	124	3,777
14	Lakeup	0	100	3,667
15	Lake	0	100	5,756

Table 2.10. Watershed numbering convention with weather station and watershed area.

Watershed Number	Watershed Name	Weather Station	Watershed Area (ha)
1	Osage	Bentonville	57,350
2	Clear	Fayetteville	20,897
3	Fork	Fayetteville	41,467
4	Flint	Kansas	32,110
5	Baron	Odell	39,214
6	Caney	Stilwell	31,568
7	Benton	Siloam Spring	37,610
8	River	Kansas	13,018
9	Bord	Kansas	33,022
10	Tyner	Kansas	10,893
11	West	Stilwell	30,450
12	Bbaron	Tahlequah	13,009
13	Bilin	Tahlequah	10,156
14	Lakeup	Tahlequah	5,379
15	Lake	Webber Fall	34,085

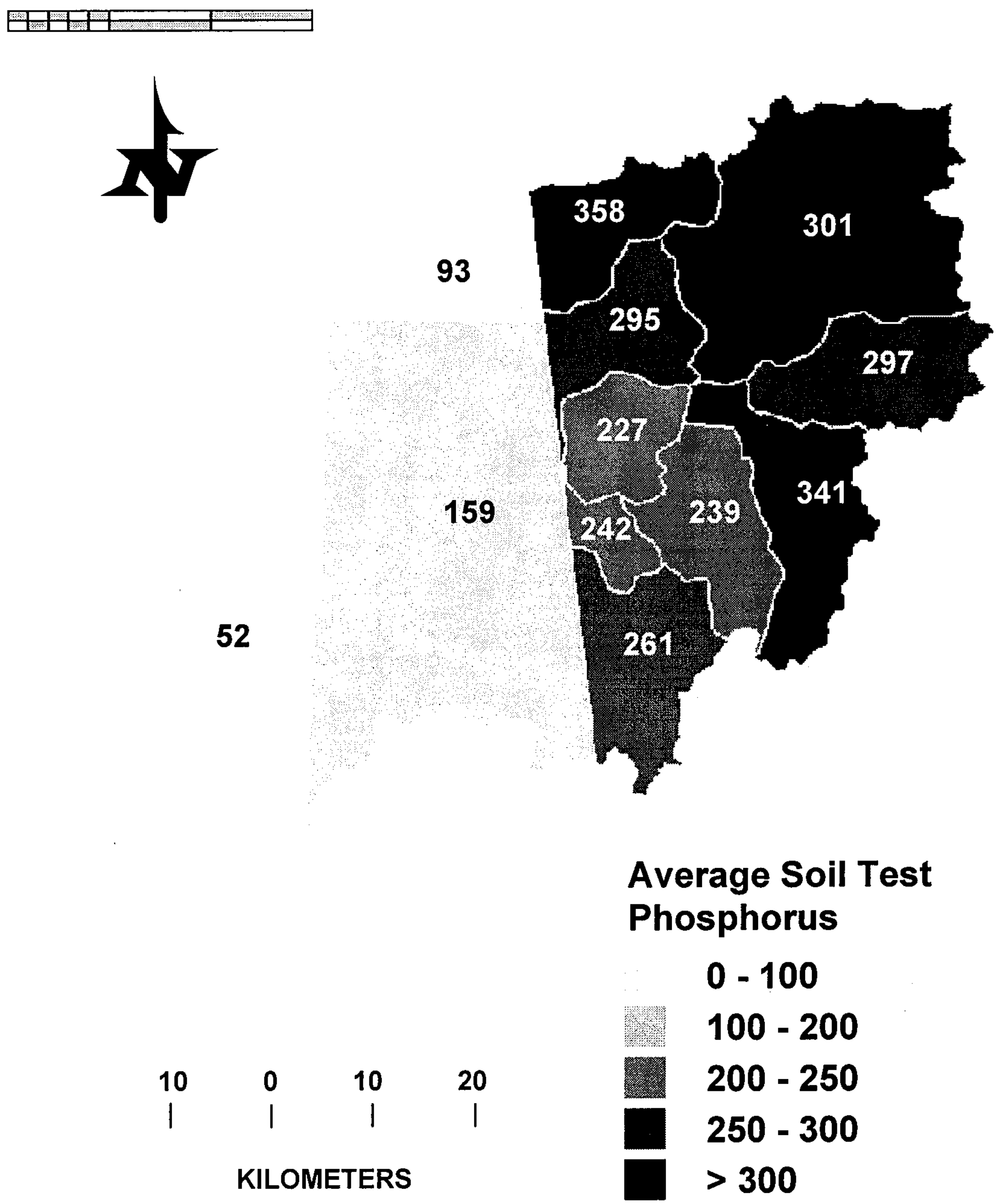


Figure 2.6 Observed average soil test phosphorus for pastures by county/watershed for the Upper Illinois River Basin.

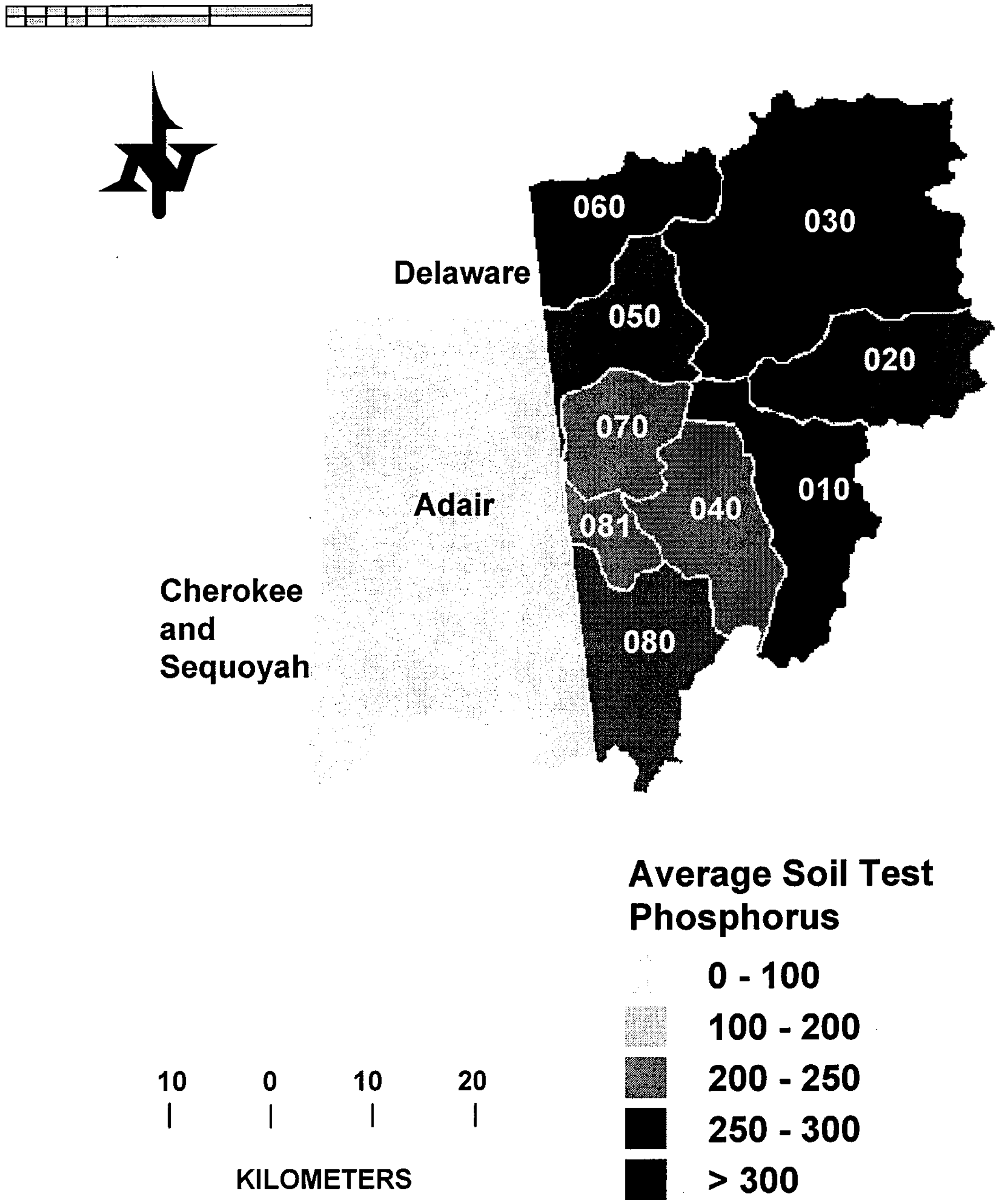


Figure 2.6 Observed average soil test phosphorus for pastures by county/watershed for the Upper Illinois River Basin.

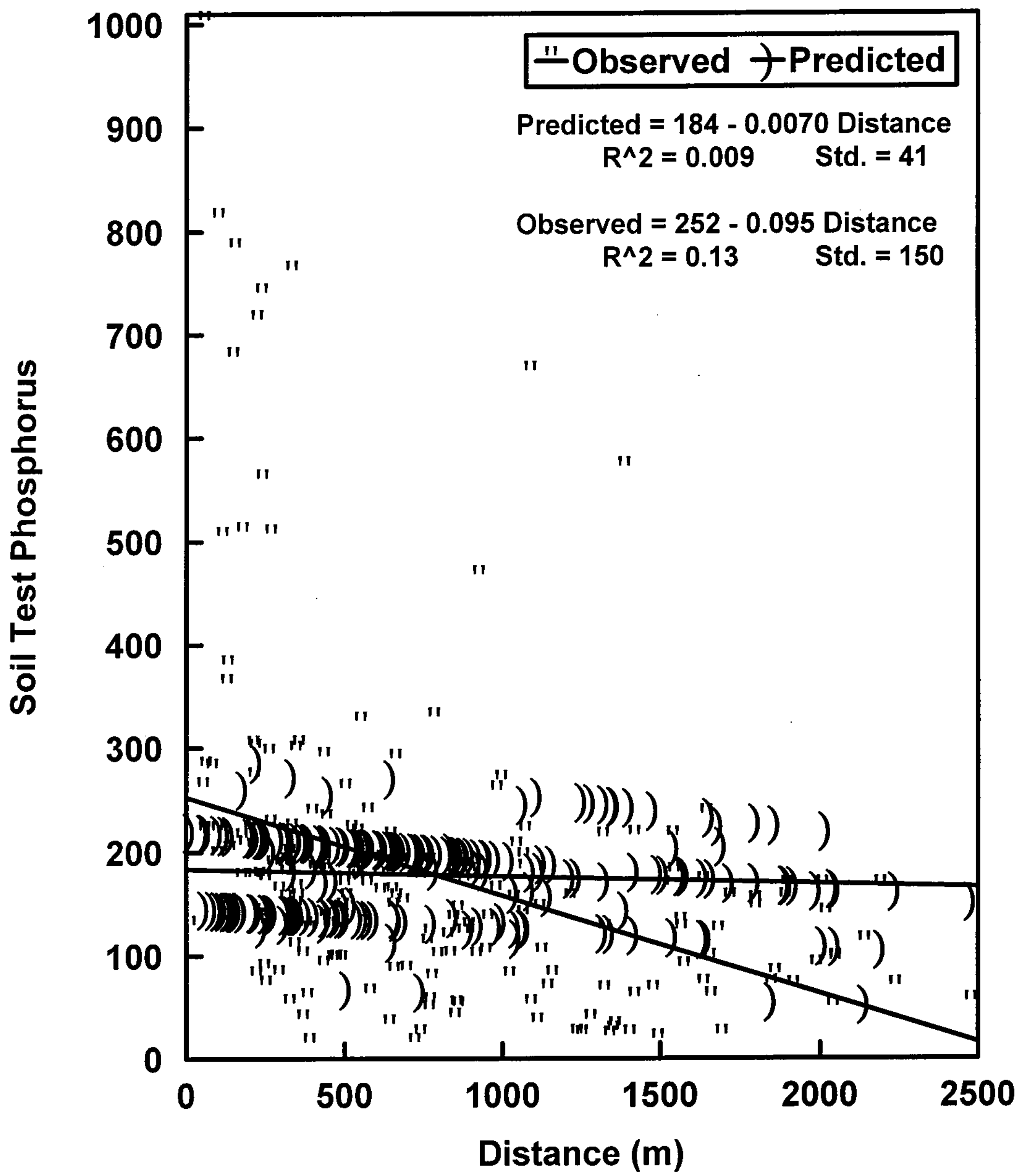


Figure 2.7. Observed and predicted soil test phosphorus for pasture related to distance from poultry house for the Peacheater Creek Watershed, Oklahoma.

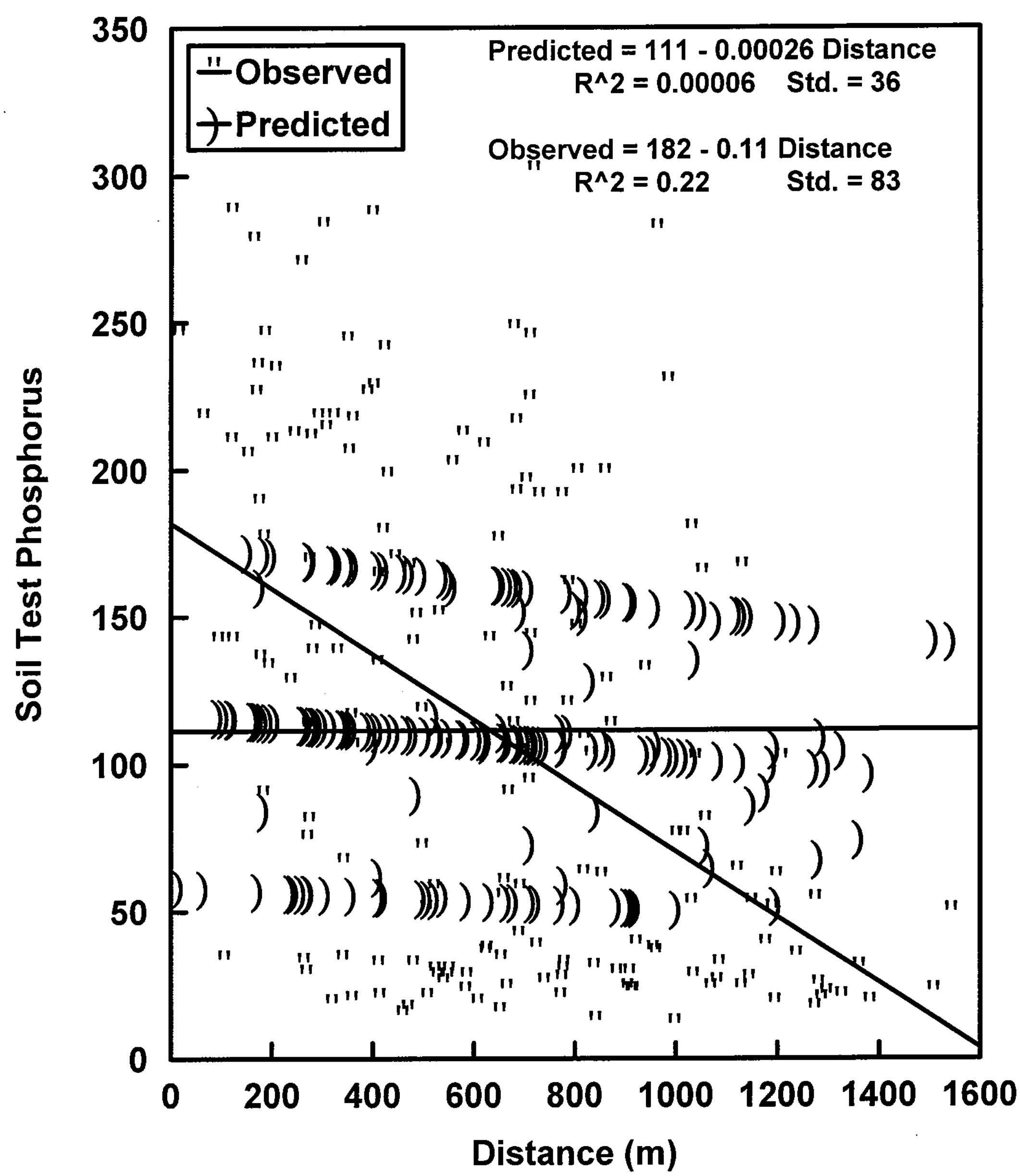


Figure 2.8. Observed and predicted soil test phosphorus for pasture related to distance from poultry house for the Battle Branch Watershed, Oklahoma.

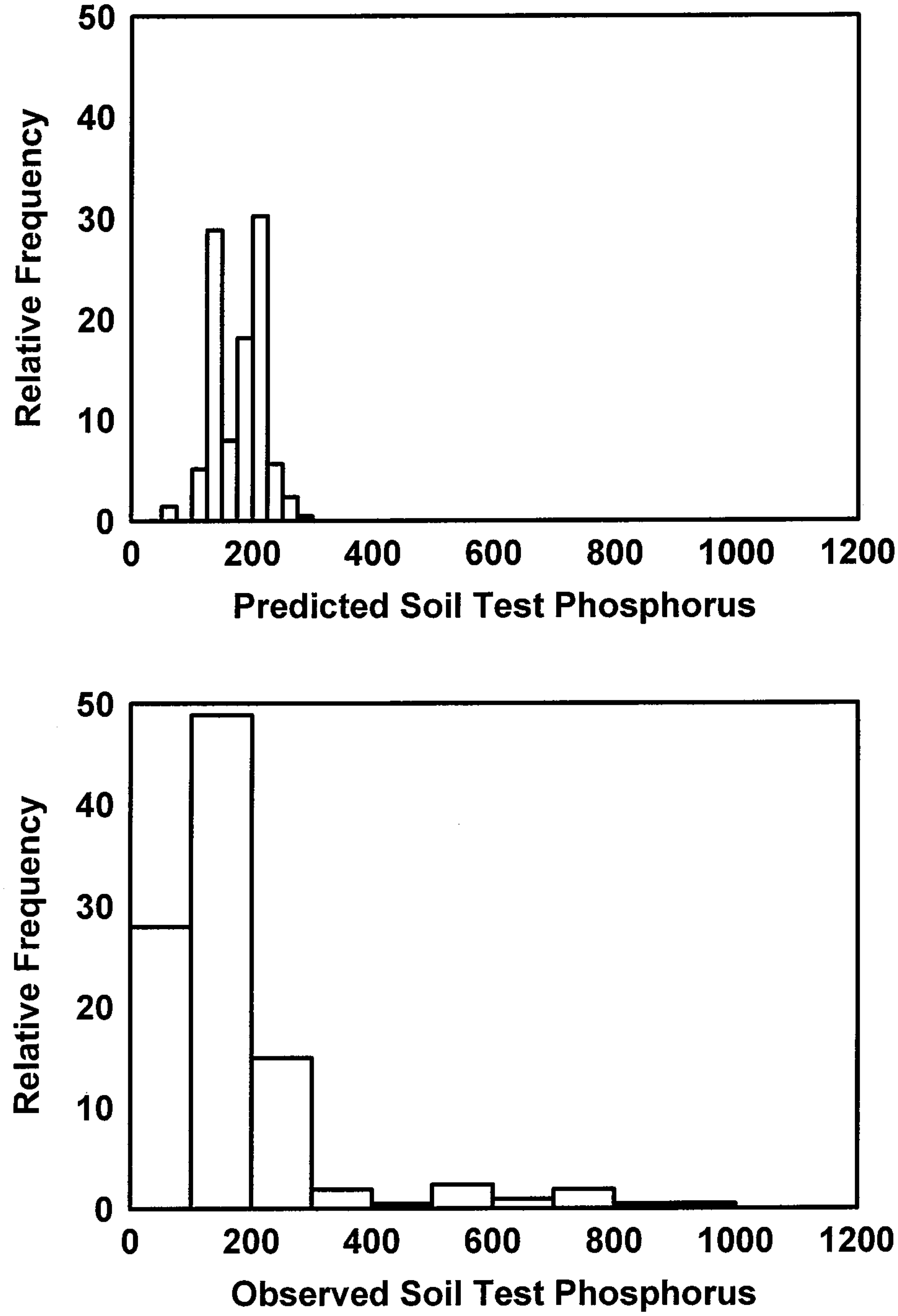
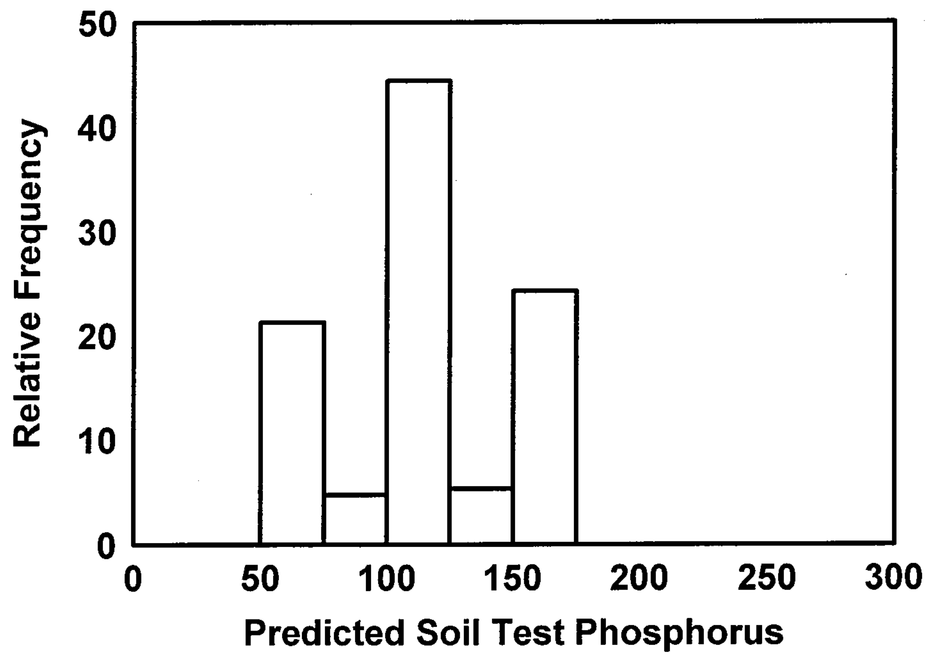


Figure 2.9. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in the Peacheater Creek Watershed, Oklahoma.



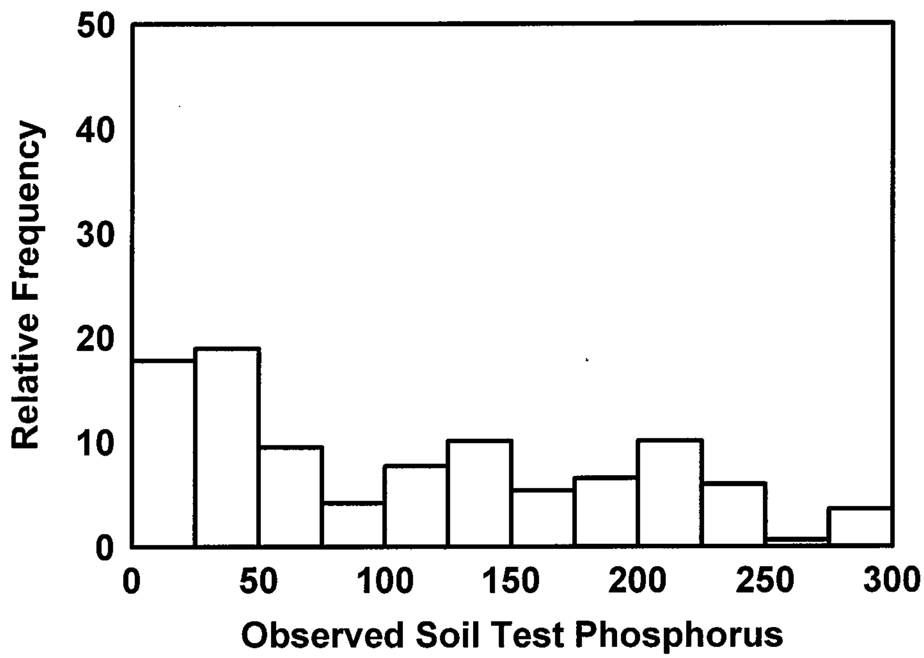


Figure 2.10. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in the Battle Branch Watershed, Oklahoma.

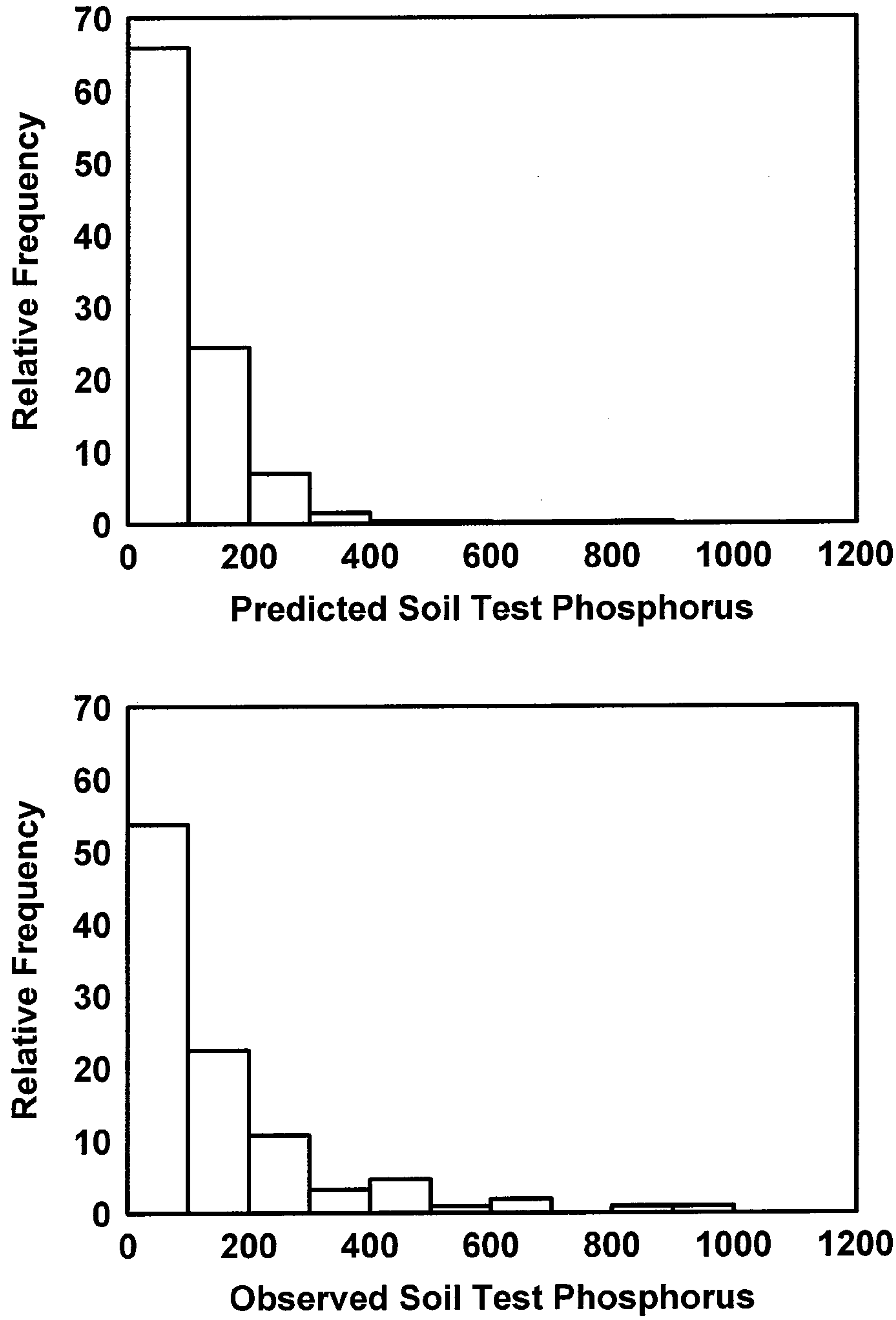


Figure 2.11. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Adair County, Oklahoma.

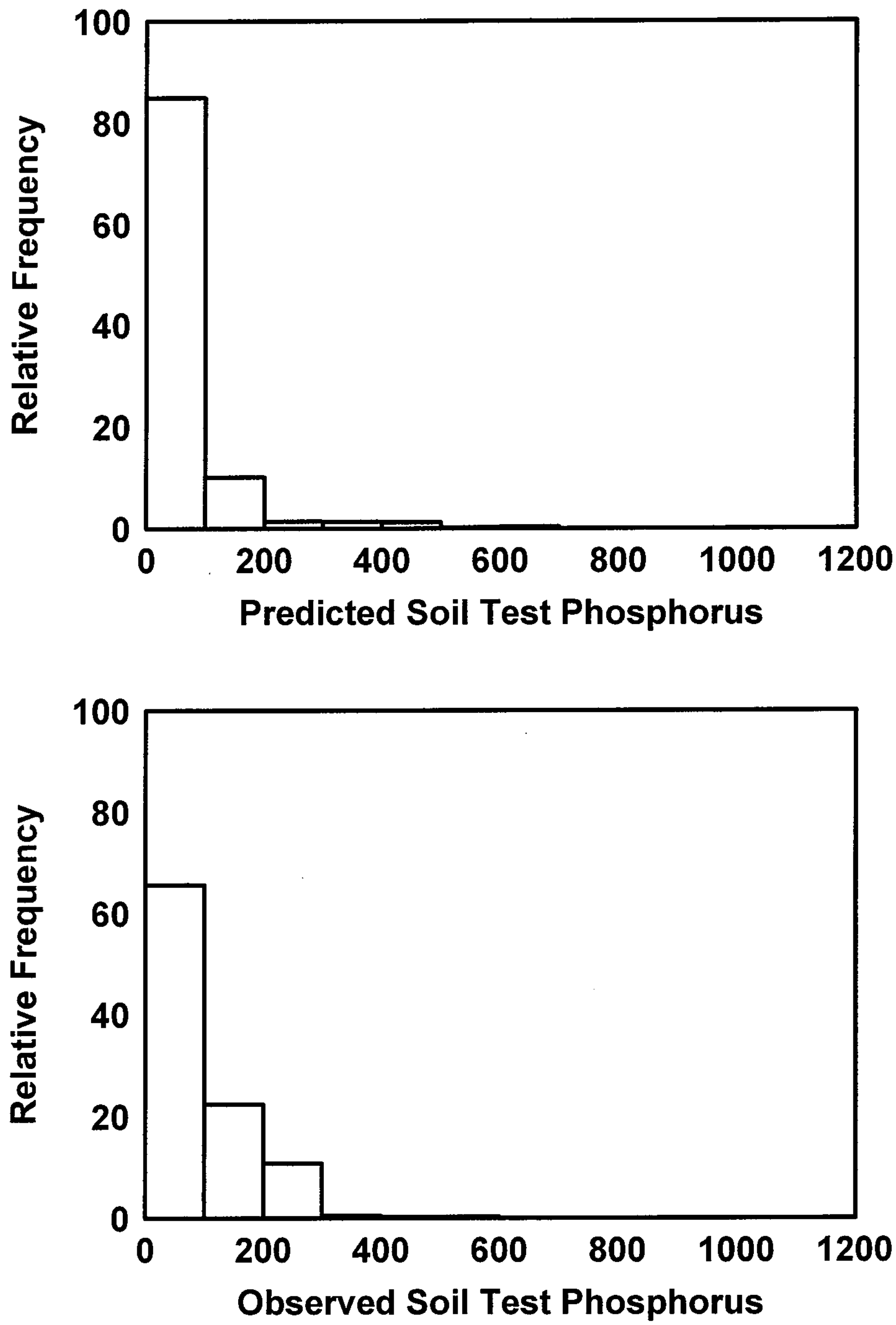
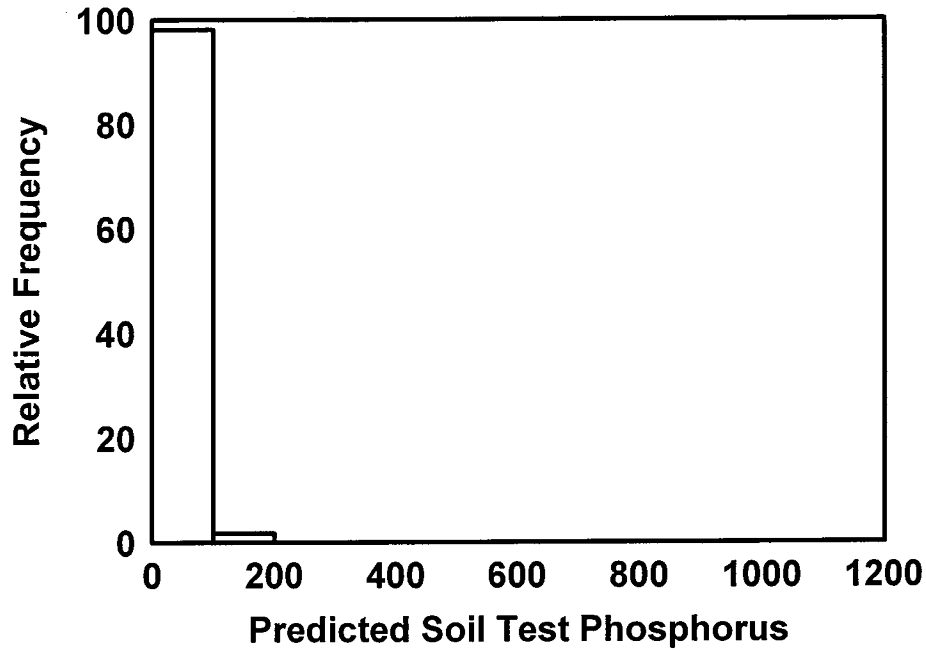


Figure 2.12. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Delaware County, Oklahoma.



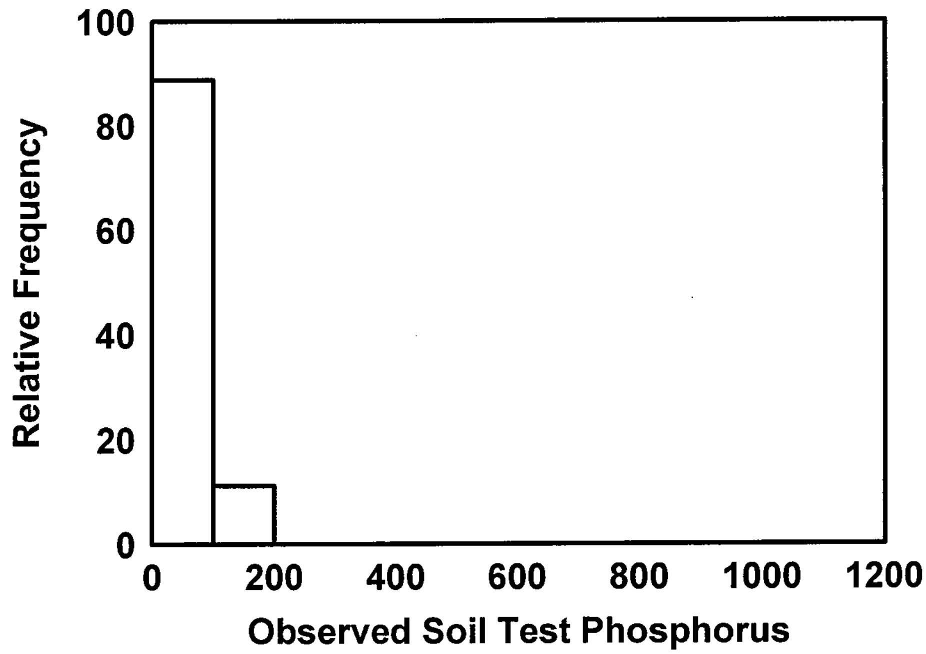
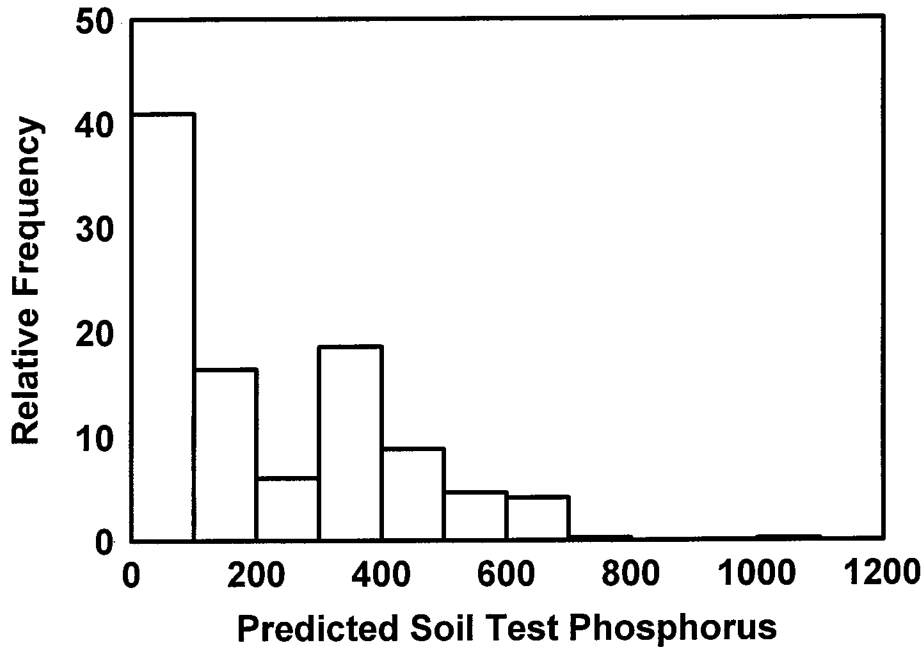


Figure 2.13. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Cherokee County, Oklahoma.



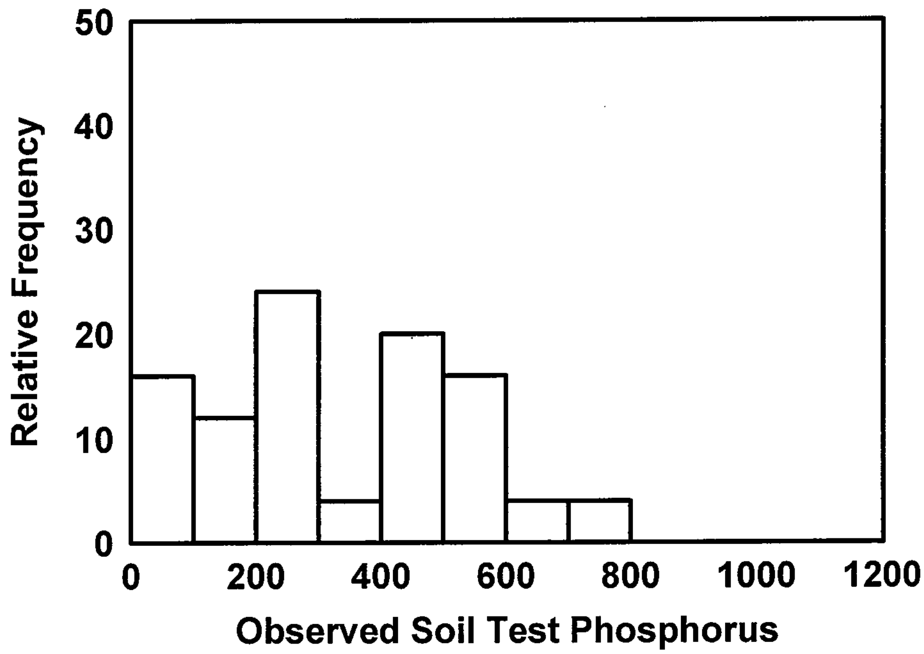


Figure 2.14. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 010, Arkansas.

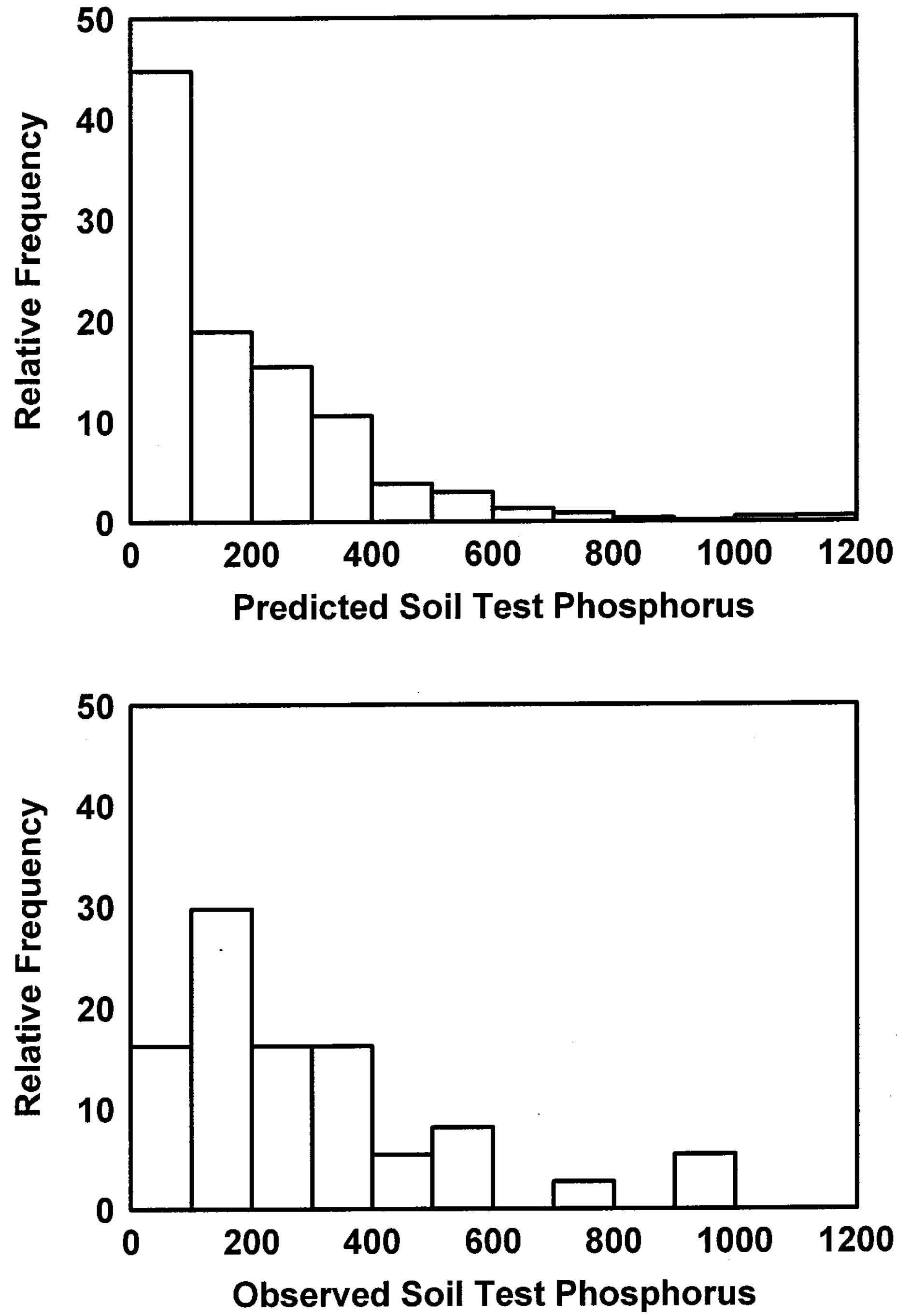


Figure 2.15. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 020, Arkansas.

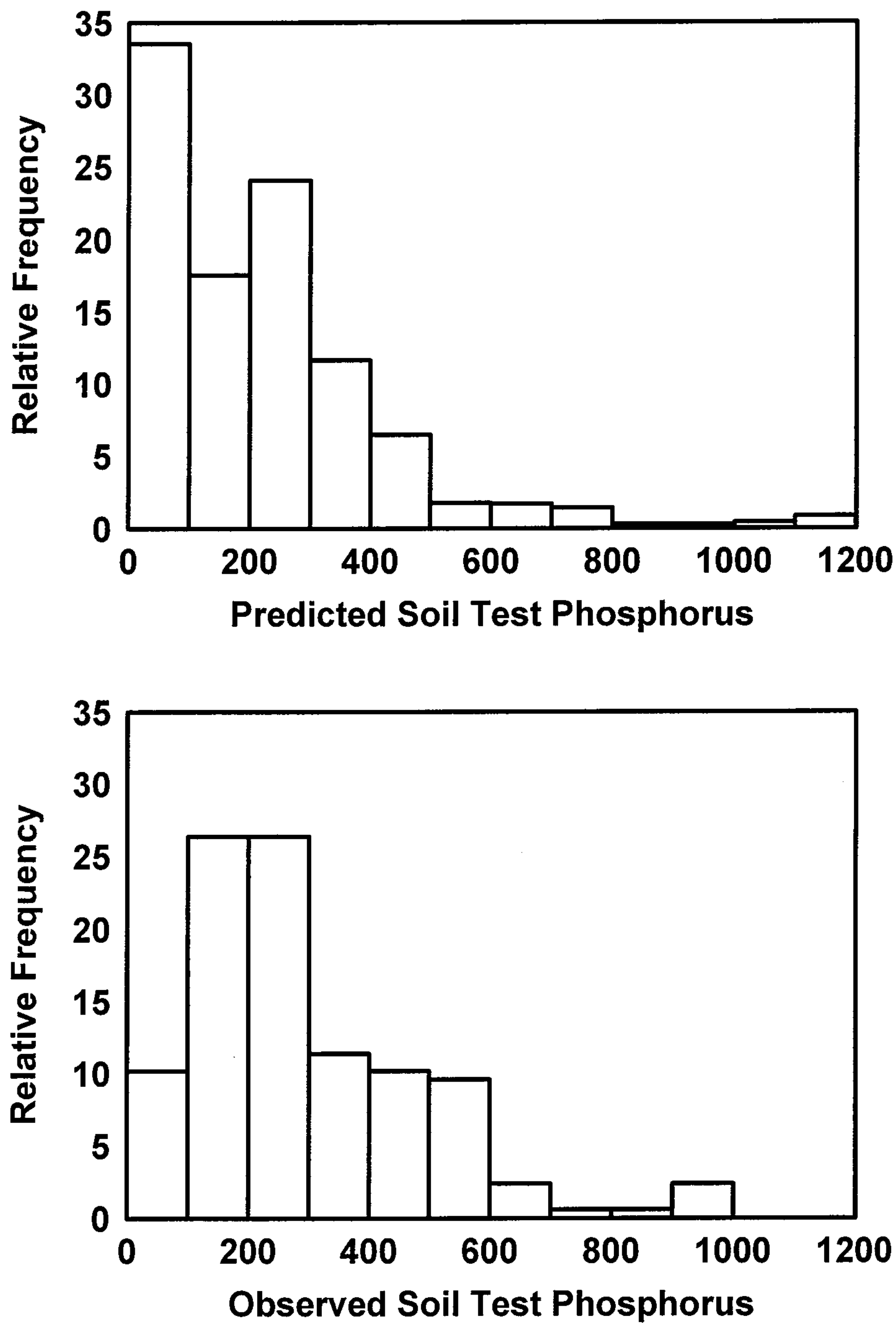


Figure 2.16. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 030, Arkansas.

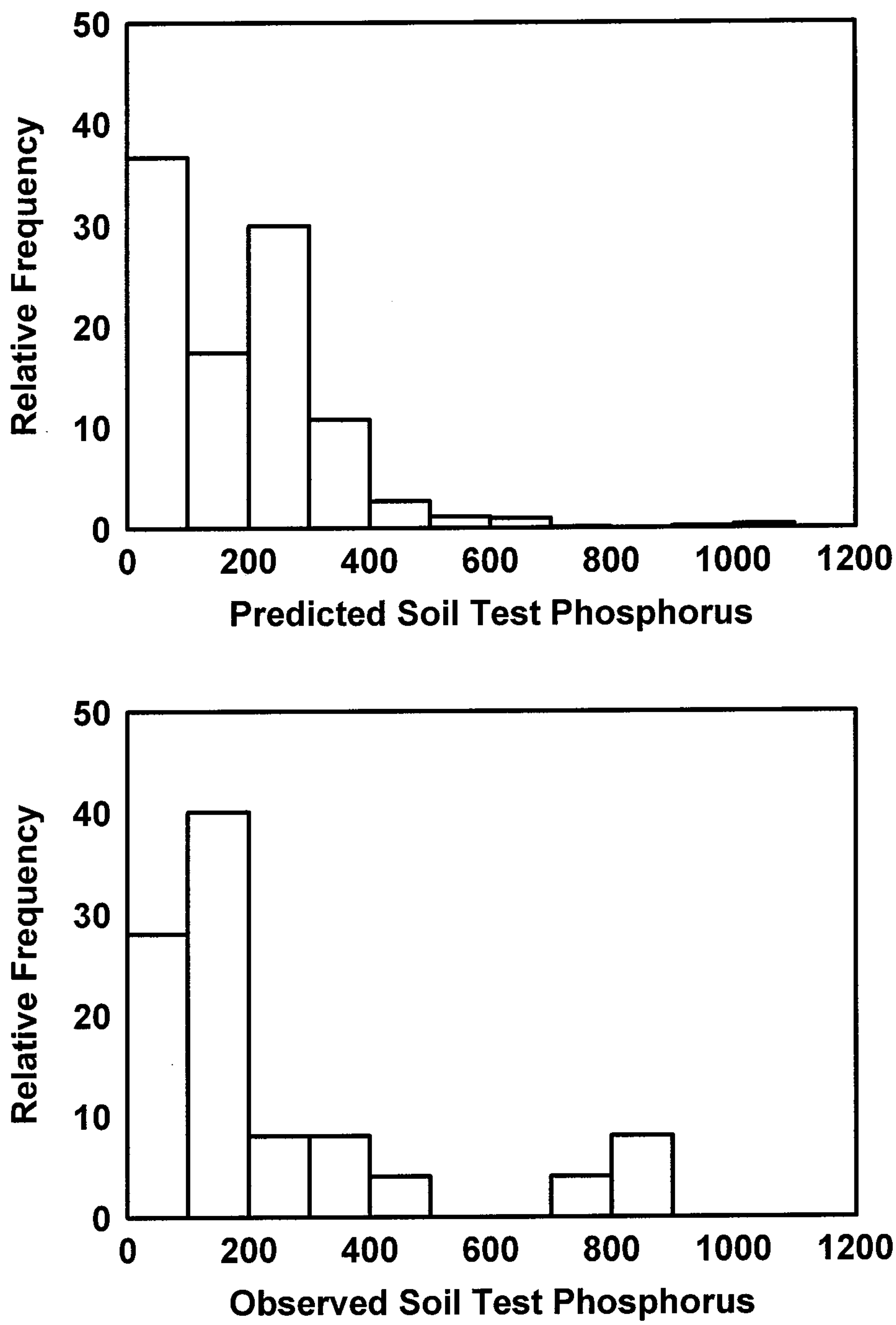


Figure 2.17. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 040, Arkansas.

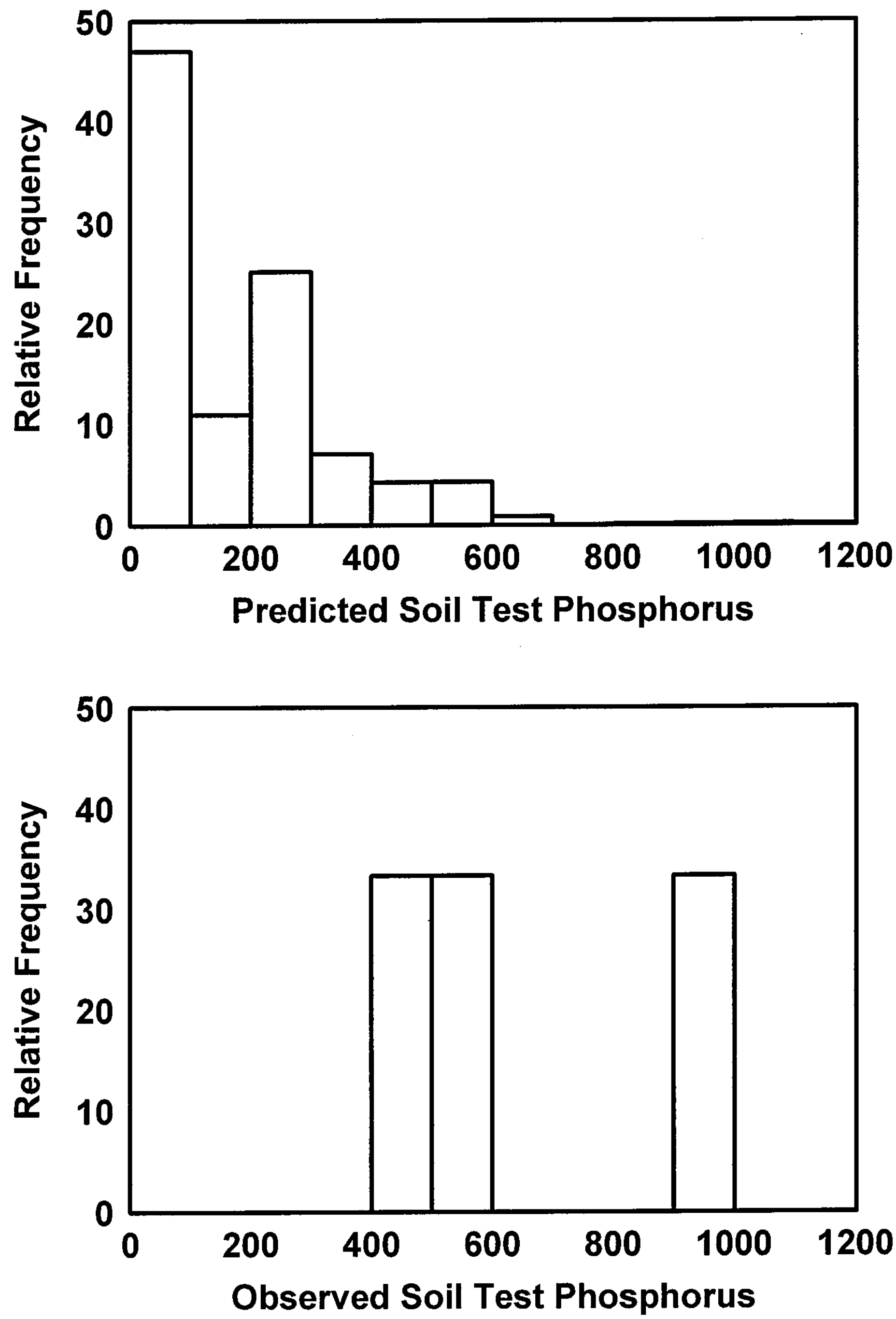


Figure 2.18. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 050, Arkansas.

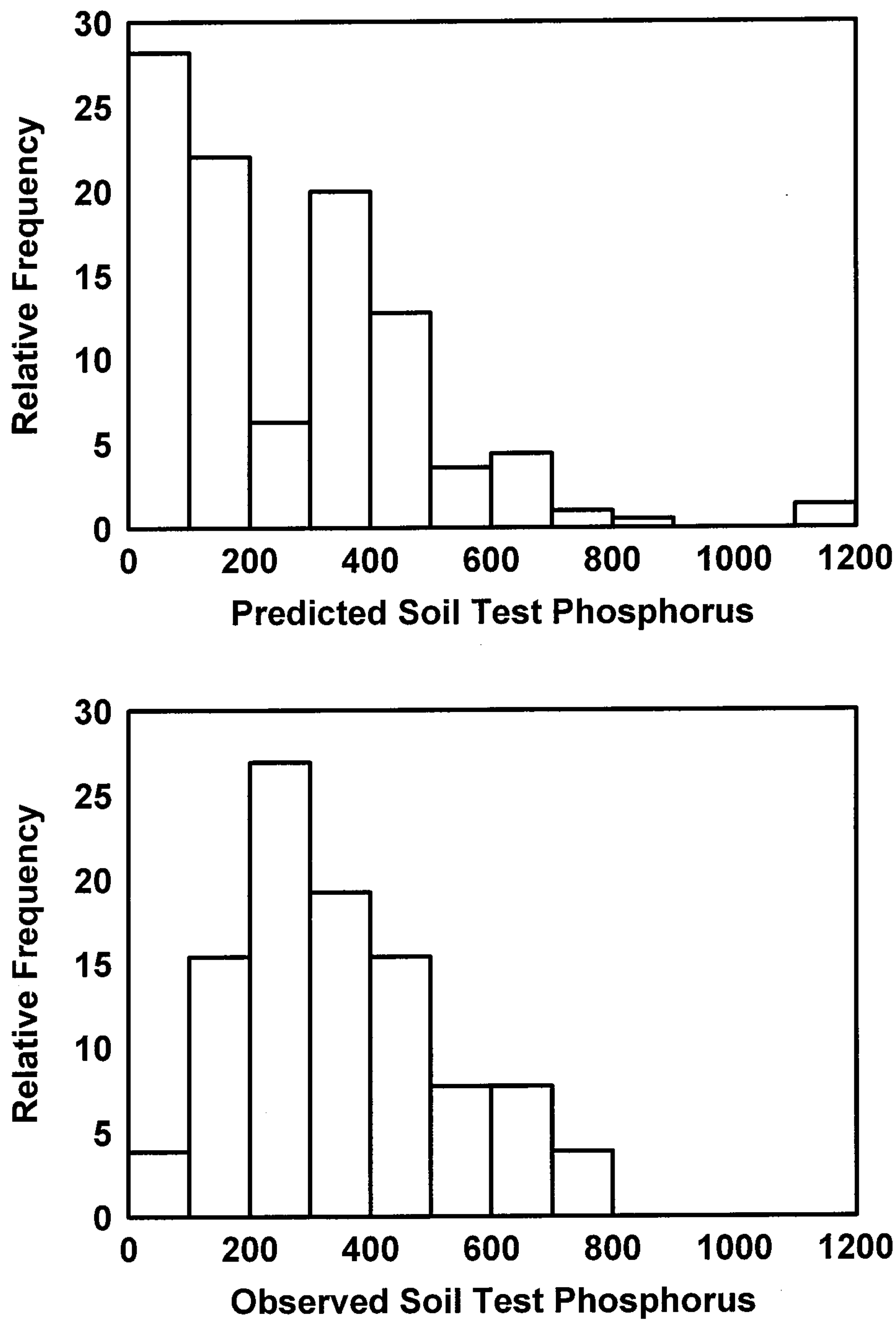
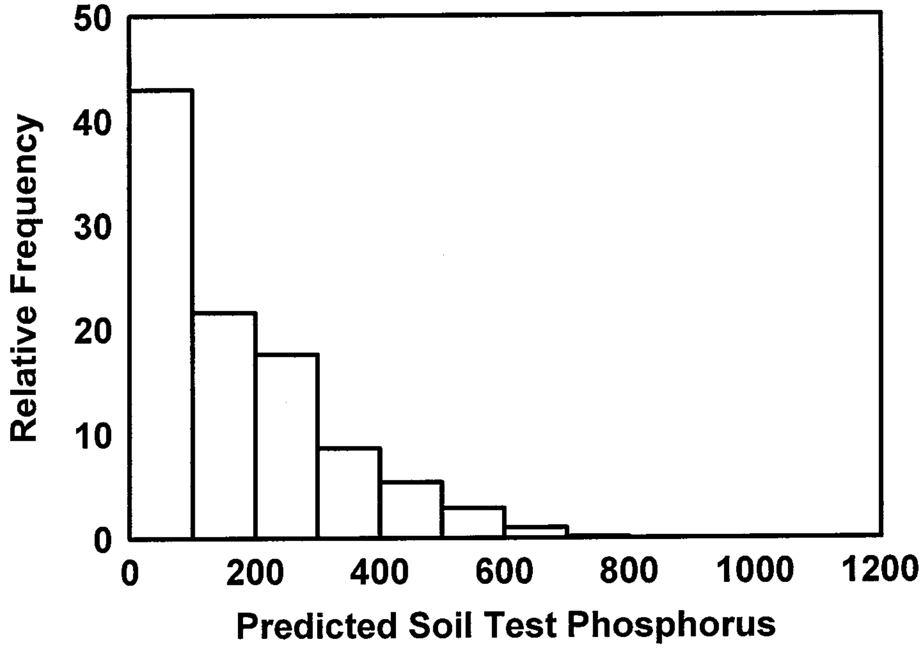


Figure 2.19. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 060, Arkansas.



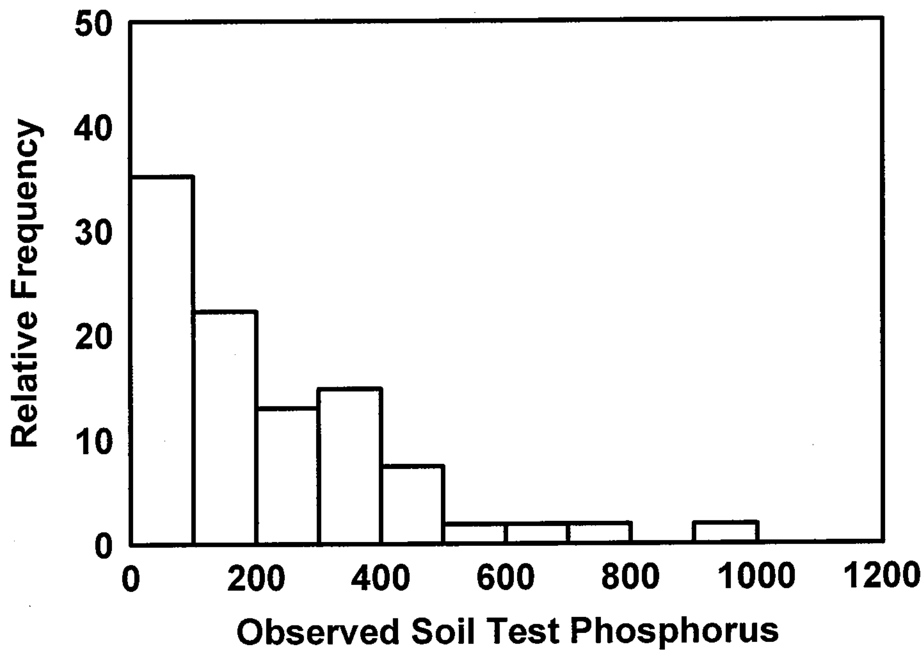


Figure 2.20. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 070, Arkansas.

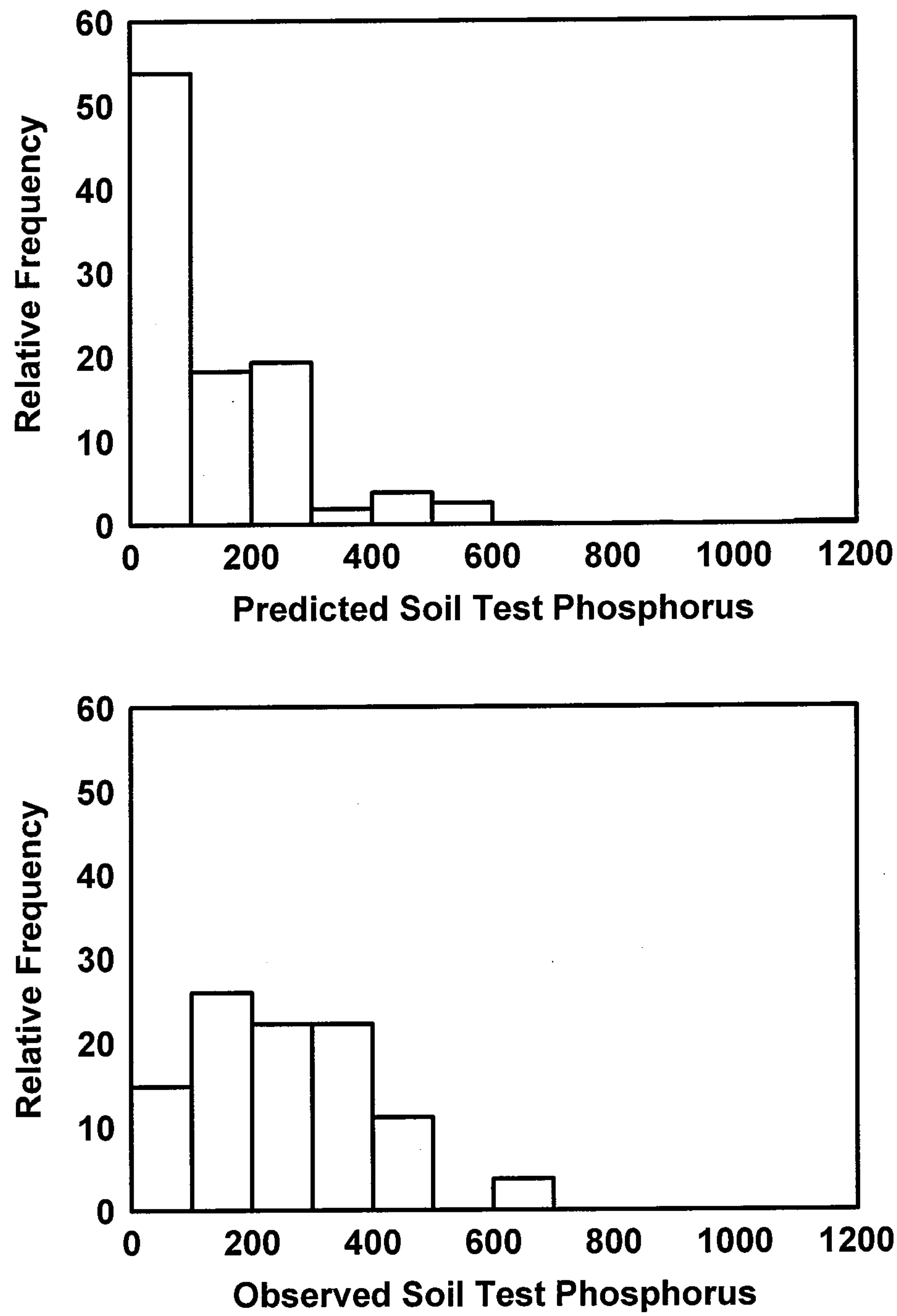
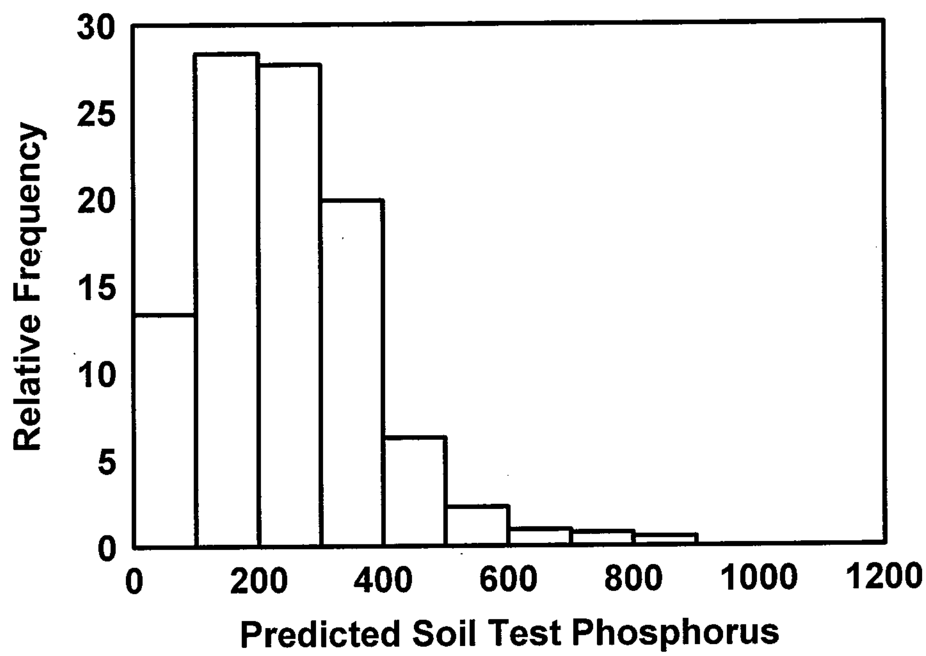


Figure 2.21. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 080, Arkansas.



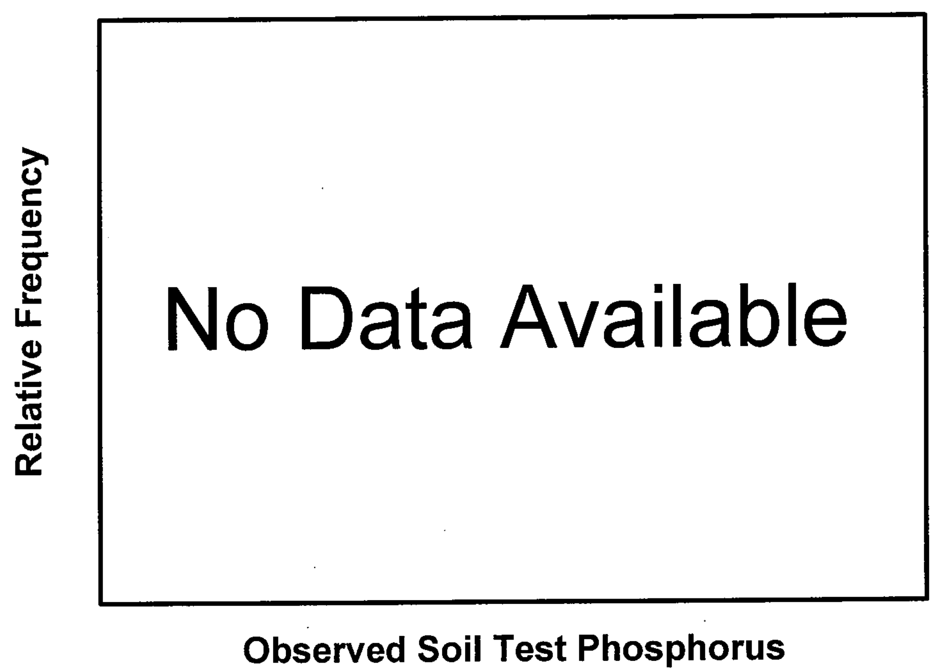


Figure 2.22. Observed and predicted relative frequency distributions of soil test phosphorus for pasture in Watershed Number 081, Arkansas.

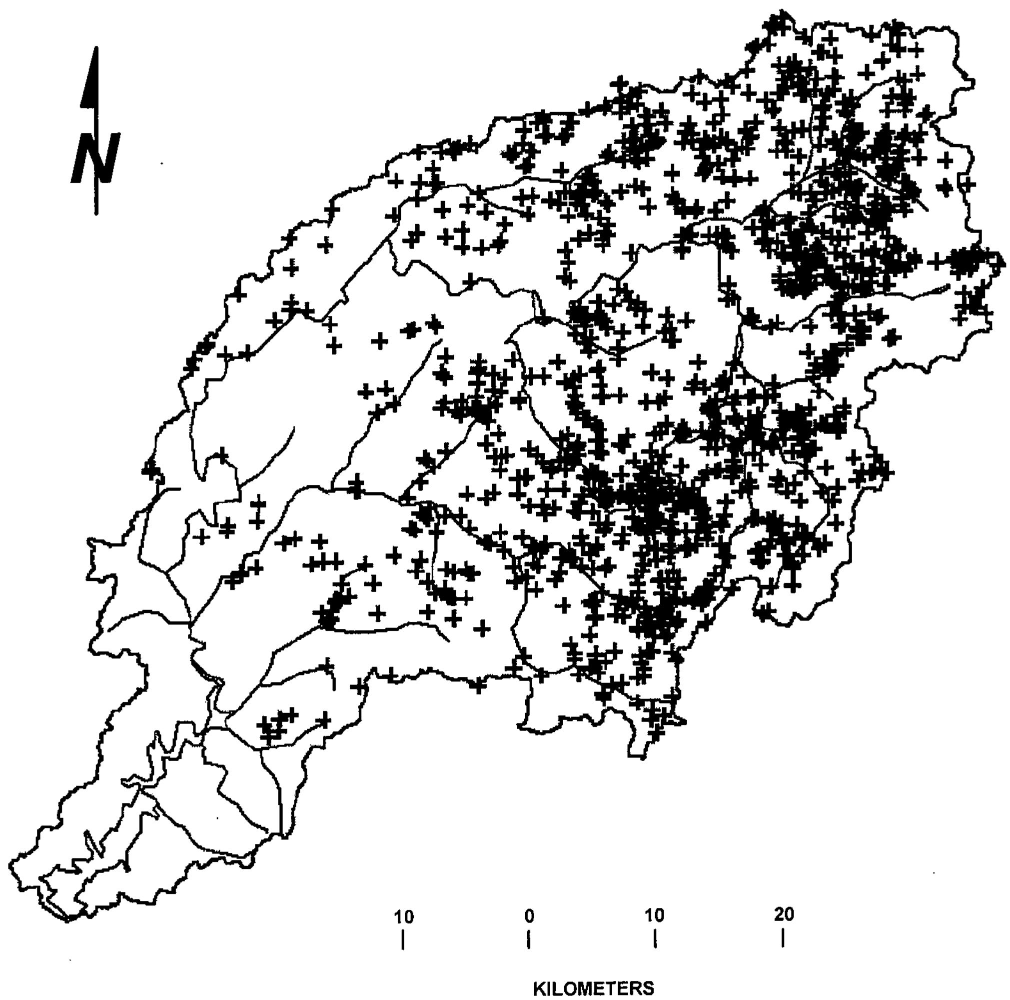


Figure 2.23. Poultry house locations for the Upper Illinois River basin.

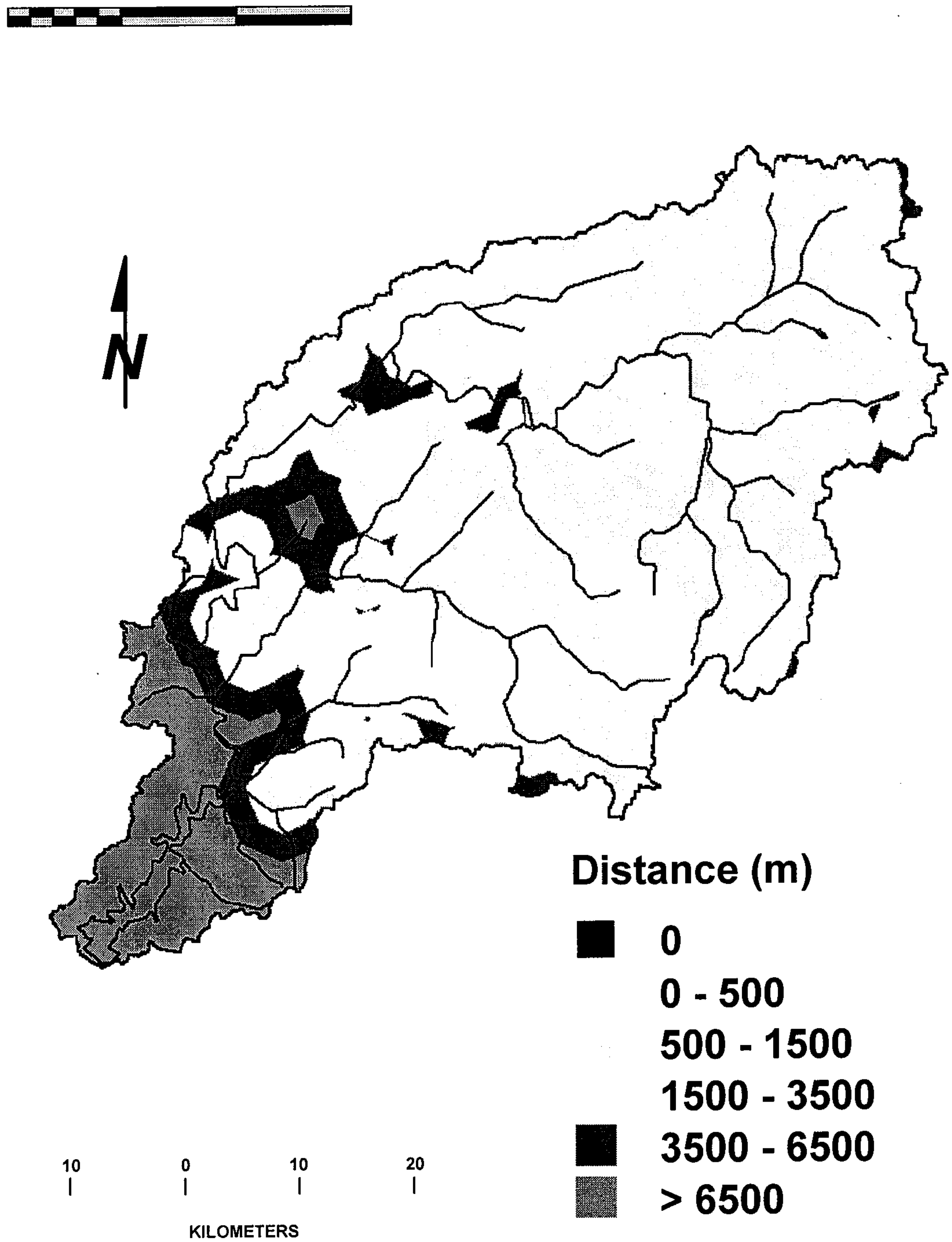


Figure 2.24. Distance from poultry house for the Upper Illinois River basin.

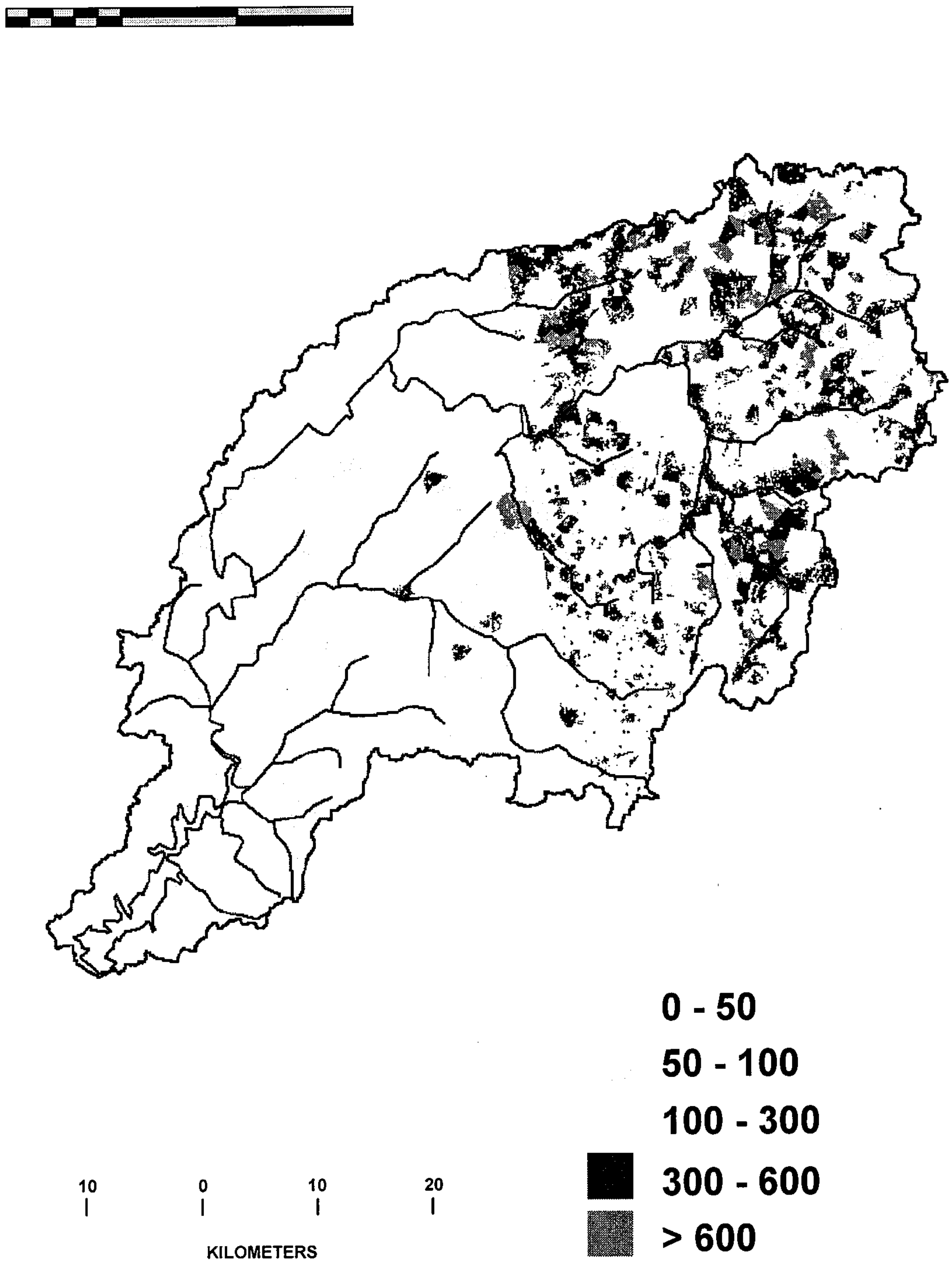


Figure 2.25. Initial soil phosphorus for the Upper Illinois River basin.

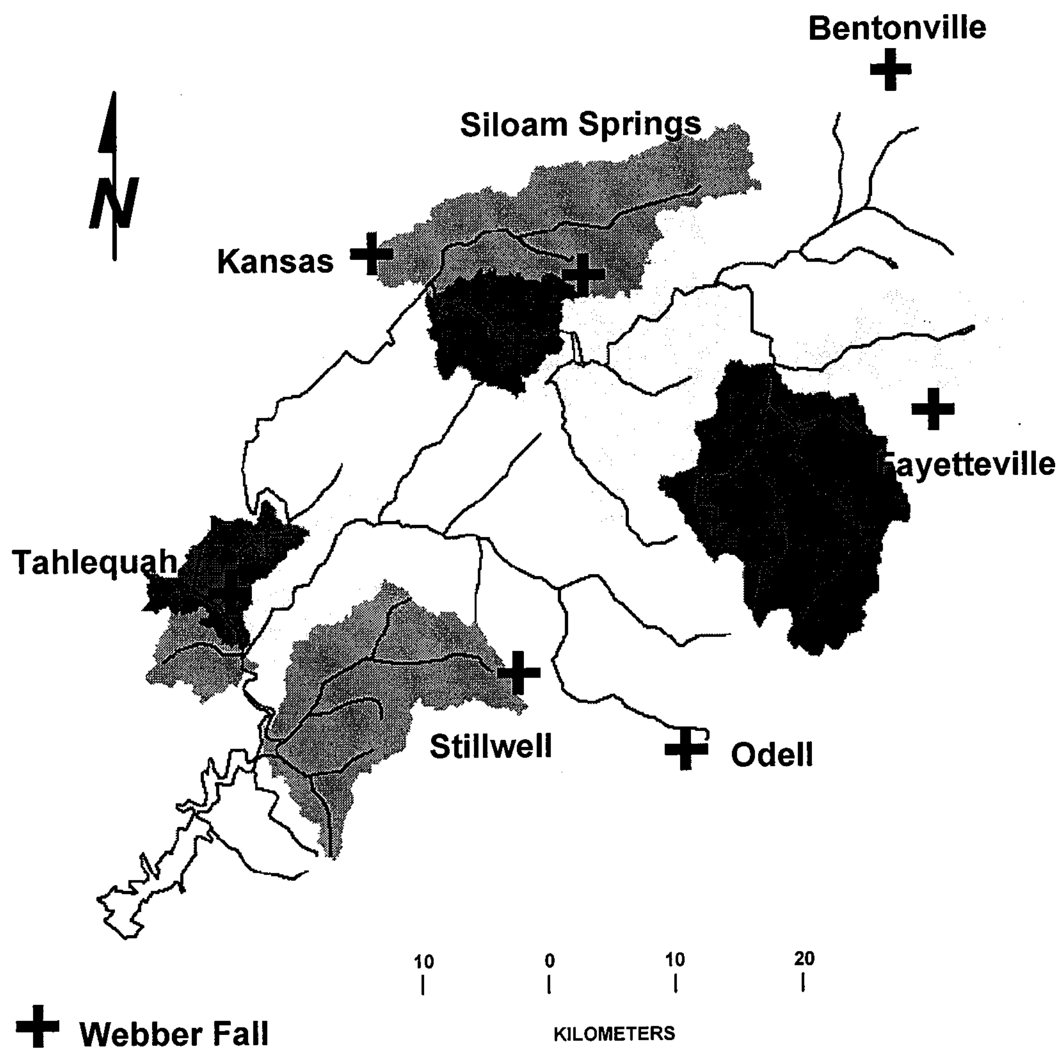


Figure 2.26. Location of weather stations for the Upper Illinois River basin.

2.5 SIMPLE SIMULATION PROCEDURES

2.5.1 Watershed Validation and Evaluation of Cell and Field Methods

SIMPLE provides two scales at which to simulate sediment and phosphorus loading: cell scale and field scale. A cell is the smallest element of a map in which the data are stored. A field is a group of adjacent cells with homogeneous land use and management practices characteristics. The field-based option requires less simulation time because there are fewer fields than cells. However, error may be introduced if there is significant parameter variation within a field. The following section compares SIMPLE simulations results for the cell and field methods to determine if SIMPLE can be applied to the Upper Illinois River Basin using the field method. In addition, a watershed level validation of SIMPLE is presented for two watersheds. It should be noted that no calibration of the SIMPLE model was applied.

2.5.1.1 Evaluation Procedure

To test the impact of cell and field level simulations SIMPLE was applied to the Battle Branch watershed in Oklahoma and the QOD subwatershed of the Owl Run watershed in Virginia. Observed data from these watersheds were compared with simulated results by means of simple linear regression. Regression was evaluated by testing hypotheses for slope (β_0) and intercept (α_0) adapted from Haan (1977) using the following equation:

$$Y = \alpha + \beta X \qquad 2.6$$

A Students t test was performed:

1. Test null hypothesis Ho $\alpha_0=0$ vs alternative Ha $\alpha_0\neq0$, using t value equal to: $t=(a-\alpha_0)/S_a$
2. Test null hypothesis Ho $\beta_0=1$ vs alternative Ha $\beta_0\neq1$ using t value equal to: $t=(b-\beta_0)/S_b$
3. Test null hypothesis Ho $\beta_0=0$ vs alternative Ha $\beta_0\neq0$ using t value equal to: $t=(b-\beta_0)/S_b$ and all three tests checked versus tabulated value of t with confidence $1-\alpha/2=0.975$ and degree of freedom of n-2.

To run the field-method simulation requires parameters averaged over all cells in a field. Parameters include curve number, the erosion factors K, C, P, slope, slope length and the distance to stream, and the phosphorus loading parameters, initial phosphorus, percent clay, pH, and percent organic carbon. A Fortran program was written to obtain the arithmetic mean of these parameters for each field using:

$$P_{AVG} = \frac{P_1 + P_2 + \ldots + P_{n-1} + P_n}{n} \qquad 2.7$$

where P_{avg} is average parameter for a given field, P_1 to P_n are parameter for each cell contained in the field and n is number of cells. These parameters were then input into SIMPLE.

2.5.1.2 Watershed Descriptions

The Battle Branch watershed is located in southern Delaware County in northeast Oklahoma. The watershed area is approximately 5500 acres. This hydrologic unit is in the Ozark Highland Land Resource Area. The topography is primarily rough steep hills with blackjack-postoak tree cover. Battle Branch is a tributary of the Illinois River. The watershed is located in one of the nations leading poultry producing areas. There are 31 chicken houses located within the unit. In addition to an intensive poultry production there are 9 dairies with 550 dairy animals and about 1000 grazed beef cattle within the watershed area. The major land use within the watershed is agriculture. The watershed area includes 19 different types of soils. Four type of soils predominate in the watershed and they are associated with the Clarksville-Baxter-Locust type: Clarksville stony silt loam with area of 845 hectares and 20 to 50 % of slopes having the highest runoff potential; Baxter Locust complex with area of 706 acres and slopes from 3 to 5%; Baxter cherty silt Loam with area of 677 acres and 1 to 3% slopes, Clarksville stony silt loam having area of 677 acres and slopes from 5 to 20%.

There are 178 different fields identified in the Battle Branch watershed; they are grouped into 6 land use types: pasture with 58% area, woods with 33% of area, Meadow-hay with 6% area, cropped land, urban, and homesteads with 3% of the area. An average annual C value of 0.003 was used for fields that are considered pasture, meadow-hay, urban and homesteads. Average annual C values of 0.001 and 0.1 were used for wood lands and cropped lands, respectively. The curve numbers (CN) were obtained based on the land use cover and the hydrologic soil group.

Daily precipitation were obtained from The National Climatic Data Center for Oklahoma (Kansas, OK weather station). Battle Branch flow and phosphorus loadings were obtained from Oklahoma Conservation Commission. Stage recorder charts were collected and kept from August 1986 to November 1987. Five storm events were sampled during the above time period. Flow measurements at three different stages were taken and plotted to develop a rating table. With the assistance of the school of Forestry at OSU all of the stage charts and rating curves were digitized. Fortran programs were used to combine two sets of data to give total flow and interval flow and to calculate nutrient summaries and total loadings from rising, falling, and baseline water quality averages.

The Owl Run watershed is located in Fauquier County, Virginia about 165 km south west from Washington D.C. The watershed area is 1153 hectares. QOD is a part of Owl Run watershed with an area of 334 hectares. Over 70% of the area is used for agriculture. The narrow, rolling to hilly uplands, underlain chiefly by granite rocks, occur between the foothills. The Rappahannock River, Coose Creek and many of their tributaries originate in the Blue Ridge and its foothills. The northern and eastern parts of the Fauquier County are drained by streams that are parts of the Potomac River drainage System.

The climate of Fauquier County, is the humid continental type with an average annual rainfall of about 104 cm. Temperatures of 32° C to 35° C in summer and -9° C to -6° C in winter are frequent extremes. The average annual rainfall in the county is fairly well distributed during whole year, although the greatest amount occurs in spring and summer. The soils on the watershed are generally shallow (0.3 to 0.6 meters deep) silt loams overlying Triassic shale. The shale layer is exposed in some areas, and the more intensely used fields are thought to be eroding at high rate. The major soil series underling the watershed are Penn, Bucks and Montalto associations which cover over 72 % of the watershed area. The Penn soils are derived from Triassic red shale and sandstone, the silt loam from the shale and the loam from the sandstone. The surface soil is reddish-brown to dark reddish brown. Slopes range from 2-7% for the undulating phase and 7 -14% for rolling phase. Runoff is medium and internal drainage is medium to rapid.

The Owl Run watershed is a part of a comprehensive nonpoint source monitoring program undertaken by the Department of Biological Systems Engineering at Virginia Tech to quantify the impacts of animal waste best management practices on water quality. Precipitation, runoff, sediment and nutrient loadings have been monitored continuously since 1986. Data describing soil characteristics and crop cover factors were obtained from the County Soil Survey for Fauquier County, Virginia, and from the Soil Conservation Service Agricultural Handbook 537 (SCS, 1978). Information describing crop practices and fertilizer applications were obtained from land owner surveys.

2.5.1.3 Battle Branch Watershed Results

Comparison between results obtained from cell and field simulations were analyzed by means of regression. For Battle Branch watershed comparison involved simulated results for a period of 16 months (August 1986 to November 1987). Statistical summaries for runoff and total phosphorus are presented in Table 2.11.

Runoff regression between field and cell level simulations showed a near perfect linear relationship indicating that the field-level simulation can be used instead of the cell level for the Battle Branch watershed. However, both methods underestimated observed runoff volume by 30 percent. Total phosphorus loss regression between field and cell simulations showed a strong relationship which indicates that field level simulations can be used instead cell simulations. Both methods of simulation overestimated observed total phosphorus yield by 100 %. The 16 months simulation results for Battle Branch watershed are presented in table 2.12.

2.5.1.4 Owl Run QOD Subwatershed Results

Comparing results obtained from cell and field simulations with observed data were analyzed using simple regression. Simulations for Owl Run watershed (QOD subwatershed) were compared with observed runoff, sediment and total phosphorus loss for a period of 18 months (January 1987 to July 1988). Statistical summaries for runoff, sediment yield and total phosphorus are presented in table 2.13.

Runoff regression between field and cell simulations showed a strong linear relationship which indicates that field simulations can be used instead of the cell simulation. Both simulation methods, cell and field, showed a fair linear relationship between observed runoff volume. Regression between field and cell simulations for sediment yield showed a strong relationship which indicates that the field method can be used instead cell simulations. Cell and field methods overestimated observed values for sediment by 69 and 62 percent, respectively. Regression between field and cell simulations for total phosphorus showed a strong linear relationship, indicating that the field method can be used. Both methods underestimated observed total phosphorus by 100 percent. The 18 months simulation results for QOD are presented in table 2.14.

2.5.1.5 Conclusions

Results obtained from simulations for the Battle Branch and QOD subwatersheds showed that field simulations provide similar results compared to cell simulation. Therefore, field scale simulations of SIMPLE were applied to the Upper Illinois River basin. The use of the field level simulations saved considerable computer simulation time and disk storage.

2.5.2 Field Boundary Delineation

To define the field boundaries we overlaid a 1500 m by 1500 m grid (225 ha cell). Using the GRASS 4.1 *r.clump* command we grouped contiguous cells with the same land use within each of the 225 ha areas. Thus each contiguous area with the same land use within each 225 ha area we defined as a separate field. We reduced the total number of fields by accumulating all minor land uses into a single field in a watershed. There was one field per watershed for the following land categories: urban, transportation and utilities, crop, orchards and vineyards, nurseries, forest, poultry operations, dairy, hog operations, and water. Forest and pasture/range land uses were not regrouped.

2.5.3 Time Scale, and Independent and Continuous Simulation Modes

To determine the number of years required to give a stable long term annual average loading sediment and phosphorus, we applied the SIMPLE model the Peacheater Creek and Battle Branch watersheds. Figure 2.27 and 2.28 show the running average annual rainfall and runoff, and sediment, and dissolved and sediment-bound P, respectively, for the Battle Branch watershed for 40 simulation years. Figures 2.29 and 2.30 show similar results for the Peacheater Creek watershed. From these figures we selected a simulation duration of 25 years (1962-1986).

The SIMPLE model was run using two simulation modes. The first mode, called the independent annual simulation mode, re-initialized all parameters to their initial value January 1 of each year. This represents the best estimator of the average current sediment and phosphorus load.

The second mode, called the continuous annual simulation mode, does not re-initialize the parameters but allows them to vary through the entire simulation period. This mode represents the expected outcome of continual land Use through the time period.

Table 2.11. Regression parameters for runoff and total phosphorus loss for Battle Branch watershed using cell-by-cell and field simulations.

Parameter/Method	R^2	Slope	Intercept
Runoff Volume			
Observed vs Cell by Cell	0.89	1.03	-1.28
Observed vs Field by Field	0.89	1.03	-1.29
Field by Field vs Cell by Cell	0.99	0.99	-0.013
Total Phosphorus Yield			
Observed vs Cell by Cell	0.66	1.88	0.003
Observed vs Field by Field	0.63	1.73	0.002
Field by Field vs Cell by Cell	0.99	0.943	-0.002

Table 2.12. Observed and SIMPLE predicted cell by cell and field monthly runoff and total phosphorus yield for Battle Branch watershed.

Month	Runoff (cm)			Total Phosphorus Yield (kg/ha)		
	Observed	Predicted Cell	Predicted Field	Observed	Predicted Cell	Predicted Field
August	0.95	0.02	0.01	0.01	0	0
September	2.42	2.82	2.8	0.07	0.06	0.05
October	25.76	27.89	27.87	0.27	0.53	0.49
November	2.58	0.46	0.45	0.05	0.01	0.01
December	0	0	0	0	0	0
January	4.77	0.14	0.12	0.04	0.02	0.01
February	7.01	0.95	0.92	0.06	0.09	0.08
March	0.80	0.59	0.58	0.02	0.05	0.05
April	0	0	0	0	0	0
May	3.82	4.87	4.84	0.04	0.39	0.38
June	0.04	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0.02	0.01	0	0	0
September	1.98	0.86	0.84	0.06	0.08	0.07
October	3.37	1.06	1.04	0.04	0.09	0.08
November	6.31	1.37	1.34	0.08	0.12	0.11
Summation	59.82	41.05	40.82	0.74	1.44	1.33

Table 2.13. Regression parameters for runoff and total phosphorus loss for QOD using cell-by-cell and field simulations.

Parameter/Method	R^2	Slope	Intercept
Runoff:			
Observed v/s Cell by Cell	0.33	0.70	0.383
Observed v/s Field by Field	0.32	0.69	0.365
Field by Field v/s Cell by cell	0.99	0.990	-0.0203
Sediment:			
Observed v/s Cell by Cell	0.73	1.27	21.24
Observed v/s Field by Field	0.43	0.85	44.14
Field by Field v/s Cell by cell	0.76	0.761	19.24
Total Phosphorus Loading:			
Observed v/s Cell by Cell	0.32	0.190	0.056
Observed v/s Field by Field	0.22	0.157	0.062
Field by Field v/s Cell by cell	0.95	0.956	0.0042

Table 2.14. Observed and SIMPLE predicted cell by cell and field monthly runoff and total phosphorus yield for QOD watershed.

	Runoff (cm)			Sediment Yield (kg/ha)			Total Phosphorus (kg/ha)		
Month	Obs-erved	Pred-icted Cell	Pred-icted Field	Obs-erved	Pred-icted Cell	Pred-icted Field	Obs-erved	Pred-icted Cell	Pred icted Field
January	1.7	2.05	1.96	18	88	60	0.1	0.08	0.08
February	4.08	1.14	1.1	20	56	49	0.43	0.05	0.052
March	0.57	0.06	0.05	1	9	10	0.01	0.01	0.007
April	6.21	3.17	3.06	19	97	203	0.26	0.13	0.18
May	0.57	0.05	0.03	8	5	0	0.02	0.01	0
June	0.15	0.11	0.09	1	41	18	0	0.03	0.015
July	0	0.01	0.01	0	0	0	0	0	0
August	0	0.03	0.03	0	2	0	0	0	0
September	2.96	9.84	9.73	211	561	469	0.25	0.53	0.5
October	0.1	0.27	0.24	1	39	23	0	0.03	0.02
November	7.09	5.58	5.52	444	537	332	1.79	0.36	0.3
December	1.86	0.43	0.39	64	42	25	0.18	0.04	0.03
January	3.1	1.28	1.26	20	61	41	0.03	0.06	0.056
February	2.1	0.28	0.24	163	33	24	0.11	0.03	0.02
March	0.6	0.19	0.16	9	16	17	0.02	0.02	0.015
April	0.4	1.39	1.37	8	34	53	0.01	0.06	0.078
May	1.6	4.14	4.11	62	157	380	0.05	0.19	0.28
June	0.1	0.03	0.03	1	2	0	0	0	0
Summation	33.39	30.05	29.47	1,050	1,780	1703	3.26	1.63	1.64

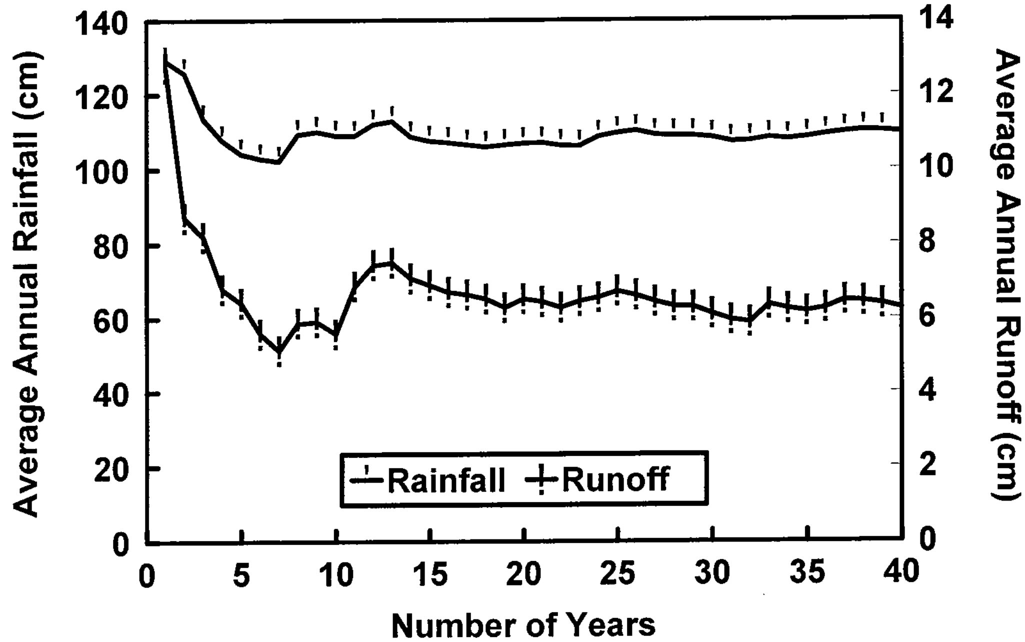


Figure 2.27. SIMPLE predicted running average annual runoff volume and rainfall for Battle Branch watershed.

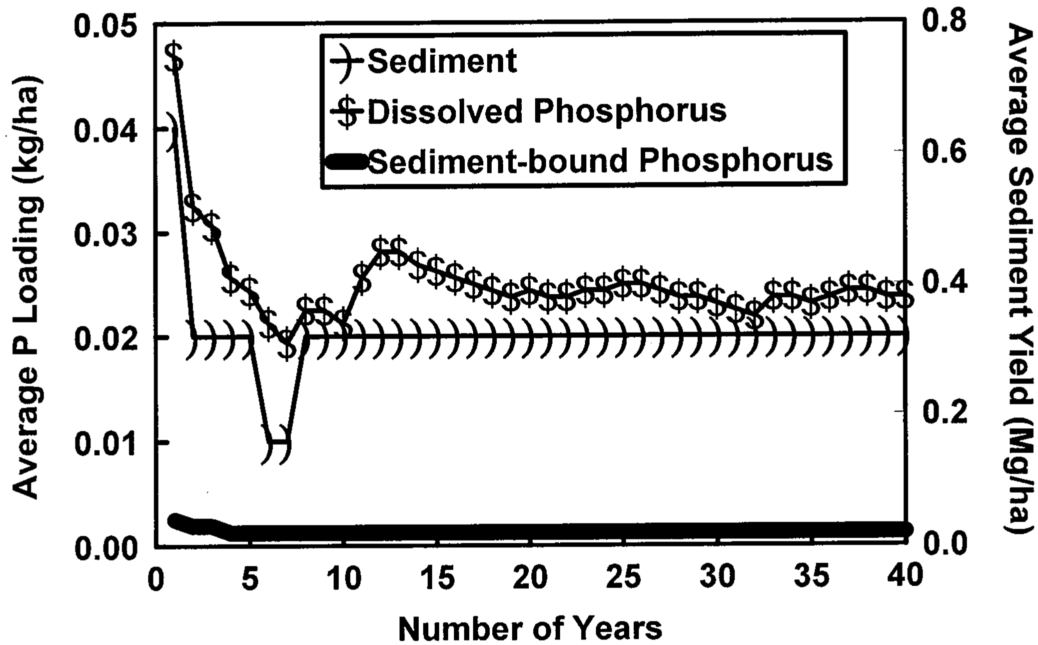


Figure 2.28. SIMPLE predicted running average annual sediment yield, and dissolved and sediment-bound phosphorus loading for Battle Branch watershed.

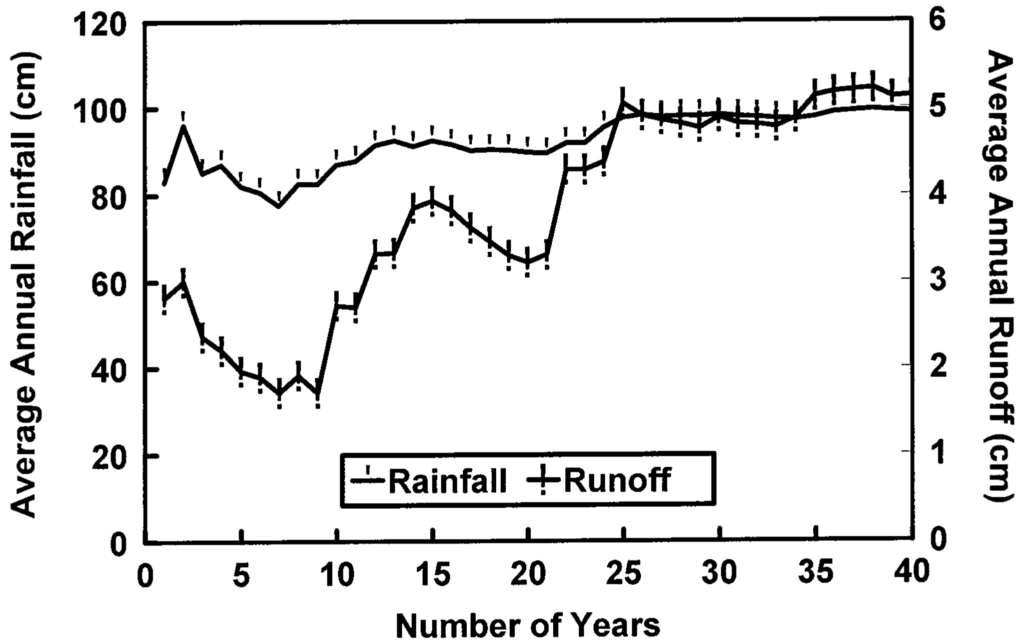


Figure 2.29. SIMPLE predicted running average annual runoff volume and rainfall for Peacheater Creek watershed.

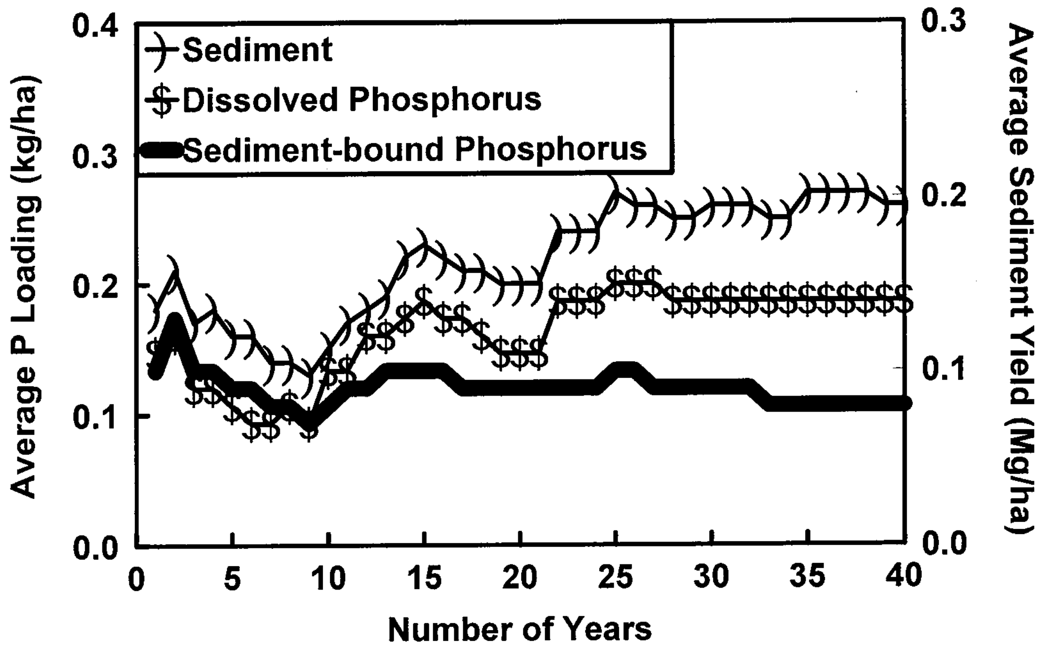


Figure 2.30. SIMPLE predicted running average annual sediment yield, and dissolved and sediment-bound phosphorus loading for Peacheater Creek watershed.

2.6 RESULTS

2.6.1 Independent Simulation Mode

For the independent simulation mode, Figures 2.31 though 2.35 give the average annual runoff volume, sediment yield, and the total, dissolved and sediment-bound phosphorus loads, respectively. Table 2.15 gives the mass loading predictions by year for the entire Upper Illinois River basin, and Table 2.16 give a summary of the average annual loading by land use. In addition, Tables 2.17 and 2.18 give the average annual mass loading and unit area loading by watershed, respectively, for the basin. Detailed average annual mass loading and unit area loading by watershed and land use are given in Tables 2.19 and 2.20, respectively. Figures 2.36 through 2.47 show the time series and relative frequency histograms for rainfall, runoff volume, sediment yield, and dissolved, sediment-bound and total phosphorus.

2.6.2 Continuous Simulation Mode

For the continuous simulation mode, Table 2.21 gives the mass loading predictions by year for the entire Upper Illinois River basin, and Table 2.22 give a summary of the average annual loading by land use. In addition, Tables 2.23 and 2.24 give the average annual mass loading and unit area loading by watershed, respectively, for the basin. Detailed average annual mass loading and unit area loading by watershed and land use are given in Tables 2.25 and 2.26, respectively.

Table 2.15. Mass loading SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode.

Year	Rain Fall (cm)	Runoff (cm)	Sediment Yield (Mg)	Soluble Phosphorus (kg)	Sediment-bound Phosphorus (kg)	Total Phosphorus (kg)
1962	101	9.1	3678	198269	626	199936
1963	64	3.2	934	53048	0	54565
1964	91	8.2	2176	160044	0	161694
1965	97	7.8	1962	153794	392	154208
1966	134	5.2	1554	83159	0	84124
1967	96	7.9	2345	160988	822	162971
1968	109	8.4	2321	164942	822	166483
1969	99	10.3	2234	211905	697	213810
1970	102	12.1	3554	273189	822	275102
1971	99	8.2	1915	145361	1011	146817
1972	96	11.8	2510	255759	1031	257430
1973	162	17.9	5302	363140	3000	365681
1974	127	21.0	4544	455778	2060	458314
1975	122	9.5	3568	206733	1684	209041
1976	83	5.5	1319	87185	0	88172
1977	94	7.1	2323	116385	430	116815
1978	97	8.5	2892	159184	619	160568
1979	92	7.4	2248	134376	392	135502
1980	64	4.3	1070	66777	0	68014
1981	98	6.2	1696	108644	321	110392
1982	98	11.5	3895	285354	601	286821
1983	86	5.2	2533	62334	0	62873
1984	117	11.2	3837	233809	2015	235518
1985	137	18.0	4363	335035	2227	337416
1986	121	22.3	6946	444310	2686	447408

Table 2.16. Unit area SIMPLE model average annual predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use.

Land Use	Runoff (cm/yr)	Sediment Yield (Mg/yr)	Soluble Phosphorus (kg/yr)	Sediment-Bound P (kg/yr)	Total Phosphorus (kg/yr)	Area (ha)
Urban	16	27	3813	4	3817	14446
Transportation & Utilities	19	3	87	0	88	1133
Crop	14	1081	1936	383	2319	3231
Pasture/Range	10	1261	185289	915	186236	202500
Orchards & Vineyards	4	229	79	48	127	1398
Nurseries	12	11	24	0	24	148
Forest	6	182	3168	51	3274	178391
Poultry Operations	112	0	0	0	0	1385
Dairy	112	0	0	0	0	67
Hog Operations	112	0	0	0	0	181
Water	112	0	0	0	0	6745

Table 2.17. Sub-basin mass loading SIMPLE model average annual predictions by land use for the Upper Illinois River Basin using the independent annual simulation mode.

Watershed Number	Watershed Name	Runoff (cm)	Sediment Yield (Mg)	Soluble Phosphorus (kg)	Sediment-Bound P (kg)	Total Phosphorus (kg)	Total Area (ha)
1	Osage	9.6	484	42645	138	42898	57350
2	Clear	9.9	136	19250	42	19342	20897
3	Fork	11.1	123	33869	0	33952	41466
4	Flint	11.7	531	24069	193	24339	32109
5	Baron	12.3	337	27654	220	27920	39214
6	Caney	6.0	269	3711	50	3824	31447
7	Benton	9.9	159	24087	45	24177	37612
8	River	9.9	72	2633	20	2673	12563
9	Bord	8.5	256	4263	53	4395	32992
10	Tyner	8.9	151	3643	55	3229	10894
11	West	5.5	182	7455	97	7174	30452
12	Bilin	8.2	35	1093	0	1101	10155
13	Bbaron	6.3	46	1337	0	1379	13009
14	Lakeup	9.5	20	521	0	523	5381
15	Lake	20.3	87	1034	0	1034	34017

Table 2.18. Sub-basin unit area SIMPLE model average annual predictions by land use for the Upper Illinois River Basin using the independent annual simulation mode.

Watershed Number	Watershed Name	Runoff (cm)	Sediment Yield (Mg/ha)	Soluble Phosphorus (kg/ha)	Sediment-Bound P (kg/ha)	Total Phosphorus (kg/ha)	Total Area (ha)
1	Osage	9.6	0.008	0.74	0.002	0.75	57350
2	Clear	9.9	0.007	0.92	0.002	0.93	20897
3	Fork	11.1	0.003	0.82	0.000	0.82	41466
4	Flint	11.7	0.017	0.75	0.006	0.76	32109
5	Baron	12.3	0.009	0.71	0.006	0.71	39214
6	Caney	6.0	0.009	0.12	0.002	0.12	31447
7	Benton	9.9	0.004	0.64	0.001	0.64	37612
8	River	9.9	0.006	0.21	0.002	0.21	12563
9	Bord	8.5	0.008	0.13	0.002	0.13	32992
10	Tyner	8.9	0.014	0.33	0.005	0.30	10894
11	West	5.5	0.006	0.24	0.003	0.24	30452
12	Bilin	8.2	0.003	0.11	0.000	0.11	10155
13	Bbaron	6.3	0.004	0.10	0.000	0.11	13009
14	Lakeup	9.5	0.004	0.10	0.000	0.10	5381
15	Lake	20.3	0.003	0.03	0.000	0.03	34017

Table 2.19. Area weighted SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg/ha)	Soluble P (kg/ha)	Sediment-bound P (kg/ha)	Total P (kg/ha)	Area (ha)
Osage	Urban	14.2	0.002	0.24	0.00	0.24	5169
	Transportation & Utilities	17.7	0.000	0.07	0.00	0.07	271
	Crop	12.4	0.187	0.56	0.07	0.62	1653
	Pasture/Range	8.3	0.002	1.05	0.00	1.06	38244
	Orchards & Vineyards	3.3	0.093	0.05	0.03	0.08	679
	Nurseries	12	0.031	0.19	0.00	0.19	7
	Forest	4.5	0.001	0.01	0.00	0.01	10555
	Poultry Operations	112	0.000	0.00	0.00	0.00	480
	Dairy	112	0.000	0.00	0.00	0.00	42
	Hog Operations	112	0.000	0.00	0.00	0.00	73
	Water	112	0.000	0.00	0.00	0.00	177
Clear	Urban	18.5	0.000	0.31	0.00	0.31	4041
	Transportation & Utilities	19.7	0.000	0.08	0.00	0.08	182
	Crop	14.5	0.217	0.66	0.09	0.75	210
	Pasture/Range	10.2	0.003	1.33	0.00	1.34	11392
	Orchards & Vineyards	4.1	0.174	0.06	0.05	0.11	164
	Nurseries	13.8	0.070	0.18	0.00	0.18	13
	Forest	6.3	0.000	0.02	0.00	0.02	4701
	Poultry Operations	108.8	0.000	0.00	0.00	0.00	115
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	108.8	0.000	0.00	0.00	0.00	4
	Water	108.8	0.000	0.00	0.00	0.00	75
Fork	Urban	15.3	0.001	0.26	0.00	0.26	606
	Transportation & Utilities	23.3	0.002	0.10	0.00	0.10	26
	Crop	15.2	0.285	0.64	0.09	0.73	152
	Pasture/Range	10.7	0.003	1.31	0.00	1.31	25411
	Orchards & Vineyards	4	0.055	0.06	0.00	0.06	77
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	9	0.000	0.03	0.00	0.03	14784
	Poultry Operations	108.8	0.000	0.00	0.00	0.00	189
	Dairy	108.8	0.000	0.00	0.00	0.00	4
	Hog Operations	108.8	0.000	0.00	0.00	0.00	18
	Water	108.8	0.000	0.00	0.00	0.00	199
Flint	Urban	17.5	0.001	0.29	0.00	0.29	1508
	Transportation & Utilities	21.5	0.002	0.09	0.00	0.09	247
	Crop	16.3	0.718	0.71	0.24	0.95	518
	Pasture/Range	11.4	0.006	1.19	0.01	1.20	19362
	Orchards & Vineyards	4.7	0.145	0.07	0.03	0.10	143
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.5	0.002	0.02	0.00	0.02	9892
	Poultry Operations	115.4	0.000	0.00	0.00	0.00	197
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	115.4	0.000	0.00	0.00	0.00	37
	Water	115.4	0.000	0.00	0.00	0.00	205

Table 2.19 (continued). Area weighted SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg/ha)	Soluble P (kg/ha)	Sediment-bound P (kg/ha)	Total P (kg/ha)	Area (ha)
Baron	Urban	19.6	0.002	0.33	0.00	0.33	169
	Transportation & Utilities	24.2	0.030	0.10	0.00	0.10	8
	Crop	18.2	1.209	0.75	0.45	1.20	108
	Pasture/Range	13.1	0.008	1.42	0.01	1.43	18976
	Orchards & Vineyards	5.8	0.240	0.08	0.05	0.14	126
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	10.5	0.001	0.03	0.00	0.03	19666
	Poultry Operations	123.7	0.000	0.00	0.00	0.00	148
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	123.7	0.000	0.00	0.00	0.00	6
	Water	123.7	0.000	0.00	0.00	0.00	7
Benton	Urban	15.7	0.004	0.26	0.00	0.26	278
	Transportation & Utilities	19.4	0.007	0.08	0.00	0.08	78
	Crop	14.2	0.120	0.63	0.03	0.65	284
	Pasture/Range	10.2	0.005	1.04	0.00	1.04	22703
	Orchards & Vineyards	4.2	0.098	0.05	0.00	0.05	7
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.2	0.001	0.02	0.00	0.02	13885
	Poultry Operations	113.3	0.000	0.00	0.00	0.00	123
	Dairy	113.3	0.000	0.00	0.00	0.00	18
	Hog Operations	113.3	0.000	0.00	0.00	0.00	29
	Water	113.3	0.000	0.00	0.00	0.00	207
River	Urban	17.5	0.001	0.29	0.00	0.29	101
	Transportation & Utilities	21.5	0.002	0.09	0.00	0.09	17
	Crop	16.4	0.065	0.72	0.00	0.72	49
	Pasture/Range	11.7	0.009	0.43	0.00	0.44	5669
	Orchards & Vineyards	0	0.000	0.00	0.00	0.00	0
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.6	0.002	0.02	0.00	0.02	6629
	Poultry Operations	115.4	0.000	0.00	0.00	0.00	11
	Dairy	115.4	0.000	0.00	0.00	0.00	3
	Hog Operations	115.4	0.000	0.00	0.00	0.00	5
	Water	115.4	0.000	0.00	0.00	0.00	79
Bord	Urban	15.8	0.090	0.26	0.05	0.31	96
	Transportation & Utilities	21.5	0.002	0.09	0.00	0.09	10
	Crop	18.4	0.394	0.60	0.00	0.60	13
	Pasture/Range	11.1	0.020	0.38	0.01	0.39	10172
	Orchards & Vineyards	0	0.000	0.00	0.00	0.00	0
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.1	0.001	0.02	0.00	0.02	22468
	Poultry Operations	115.4	0.000	0.00	0.00	0.00	38
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	115.4	0.000	0.00	0.00	0.00	5
	Water	115.4	0.000	0.00	0.00	0.00	190

Table 2.19 (continued). Area weighted SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg/ha)	Soluble P (kg/ha)	Sediment-bound P (kg/ha)	Total P (kg/ha)	Area (ha)
Tyner	Urban	17.5	0.013	0.29	0.01	0.30	2
	Transportation & Utilities	21.5	0.002	0.09	0.00	0.09	20
	Crop	15	0.495	0.37	0.00	0.38	6
	Pasture/Range	11.1	0.022	0.57	0.01	0.58	5395
	Orchards & Vineyards	0	0.000	0.00	0.00	0.00	0
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.6	0.002	0.02	0.00	0.02	5462
	Poultry Operations	115.4	0.000	0.00	0.00	0.00	7
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	115.4	0.000	0.00	0.00	0.00	2
	Water	115.4	0.000	0.00	0.00	0.00	0
West	Urban	12.7	0.000	0.22	0.00	0.22	174
	Transportation & Utilities	13.4	0.011	0.06	0.00	0.06	15
	Crop	9.7	0.456	0.47	0.24	0.70	96
	Pasture/Range	6.7	0.008	0.48	0.01	0.49	14911
	Orchards & Vineyards	4.1	0.015	0.06	0.00	0.06	11
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	3.8	0.001	0.01	0.00	0.01	15148
	Poultry Operations	84.2	0.000	0.00	0.00	0.00	51
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	84.2	0.000	0.00	0.00	0.00	1
	Water	84.2	0.000	0.00	0.00	0.00	45
Caney	Urban	12	0.002	0.20	0.00	0.20	415
	Transportation & Utilities	13.4	0.006	0.06	0.00	0.06	48
	Crop	9	1.077	0.43	0.50	0.92	77
	Pasture/Range	6.9	0.008	0.28	0.01	0.29	11988
	Orchards & Vineyards	2.5	1.519	0.04	0.26	0.30	40
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	4.3	0.001	0.01	0.00	0.01	18640
	Poultry Operations	84.2	0.000	0.00	0.00	0.00	16
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	84.2	0.000	0.00	0.00	0.00	1
	Water	84.2	0.000	0.00	0.00	0.00	222
Bbaron	Urban	11.7	0.003	0.20	0.00	0.20	41
	Transportation & Utilities	14.3	0.001	0.06	0.00	0.06	42
	Crop	10.7	0.271	0.43	0.08	0.51	28
	Pasture/Range	7.7	0.006	0.24	0.00	0.25	5077
	Orchards & Vineyards	0	0.000	0.00	0.00	0.00	0
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	4.3	0.001	0.01	0.00	0.01	7725
	Poultry Operations	83.9	0.000	0.00	0.00	0.00	9
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	0	0.000	0.00	0.00	0.00	0
	Water	83.9	0.000	0.00	0.00	0.00	87

Table 2.19 (continued). Area weighted SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg/ha)	Soluble P (kg/ha)	Sediment-bound P (kg/ha)	Total P (kg/ha)	Area (ha)
Bilin	Urban	12.3	0.003	0.21	0.00	0.21	1260
	Transportation & Utilities	15	0.007	0.06	0.00	0.06	94
	Crop	12.5	0.016	0.59	0.00	0.59	19
	Pasture/Range	9	0.006	0.20	0.00	0.20	3777
	Orchards & Vineyards	0	0.000	0.00	0.00	0.00	0
	Nurseries	11.3	0.111	0.15	0.00	0.15	50
	Forest	4.3	0.001	0.01	0.00	0.01	4827
	Poultry Operations	83.9	0.000	0.00	0.00	0.00	1
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	0	0.000	0.00	0.00	0.00	0
	Water	83.9	0.000	0.00	0.00	0.00	127
Lakeup	Urban	13.6	0.000	0.23	0.00	0.23	167
	Transportation & Utilities	17.6	0.002	0.07	0.00	0.07	14
	Crop	15.8	0.160	0.76	0.06	0.81	2
	Pasture/Range	10.5	0.003	0.12	0.00	0.12	3667
	Orchards & Vineyards	7.5	0.103	0.12	0.04	0.15	25
	Nurseries	11.7	0.057	0.17	0.00	0.17	78
	Forest	5.8	0.002	0.02	0.00	0.02	1418
	Poultry Operations	0	0.000	0.00	0.00	0.00	0
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	0	0.000	0.00	0.00	0.00	0
	Water	83.9	0.000	0.00	0.00	0.00	10
Lake	Urban	13.2	0.000	0.22	0.00	0.22	419
	Transportation & Utilities	16.4	0.009	0.07	0.00	0.07	61
	Crop	13.2	0.002	0.61	0.00	0.61	16
	Pasture/Range	9.4	0.007	0.10	0.00	0.10	5756
	Orchards & Vineyards	3.3	0.145	0.04	0.01	0.04	126
	Nurseries	0	0.000	0.00	0.00	0.00	0
	Forest	6.7	0.001	0.02	0.00	0.02	22591
	Poultry Operations	0	0.000	0.00	0.00	0.00	0
	Dairy	0	0.000	0.00	0.00	0.00	0
	Hog Operations	0	0.000	0.00	0.00	0.00	0
	Water	93.2	0.000	0.00	0.00	0.00	5115

Table 2.20. Mass loading SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg)	Soluble P (kg)	Sediment-bound P (kg)	Total P (kg)	Area (ha)
Osage	Urban	14.2	10.3	1241	0	1241	5169
	Transportation & Utilities	17.7	0.0	20	0	20	271
	Crop	12.4	309.1	917	107	1025	1653
	Pasture/Range	8.3	76.5	40309	76	40386	38244
	Orchards & Vineyards	3.3	63.1	35	17	52	679
	Nurseries	12	0.2	1	0	1	7
	Forest	4.5	10.6	137	0	137	10555
	Poultry Operations	112	0.0	0	0	0	480
	Dairy	112	0.0	0	0	0	42
	Hog Operations	112	0.0	0	0	0	73
	Water	112	0.0	0	0	0	177
Clear	Urban	18.5	0.0	1265	0	1265	4041
	Transportation & Utilities	19.7	0.0	15	0	15	182
	Crop	14.5	45.6	139	18	157	210
	Pasture/Range	10.2	34.2	15197	34	15231	11392
	Orchards & Vineyards	4.1	28.5	10	8	18	164
	Nurseries	13.8	0.9	2	0	2	13
	Forest	6.3	0.0	85	0	85	4701
	Poultry Operations	108.8	0.0	0	0	0	115
	Dairy	0	0.0	0	0	0	0
	Hog Operations	108.8	0.0	0	0	0	4
	Water	108.8	0.0	0	0	0	75
Fork	Urban	15.3	0.6	156	0	156	606
	Transportation & Utilities	23.3	0.1	2	0	2	26
	Crop	15.2	43.3	98	14	111	152
	Pasture/Range	10.7	76.2	33238	51	33314	25411
	Orchards & Vineyards	4	4.2	5	0	5	77
	Nurseries	0	0.0	0	0	0	0
	Forest	9	0.0	370	0	370	14784
	Poultry Operations	108.8	0.0	0	0	0	189
	Dairy	108.8	0.0	0	0	0	4
	Hog Operations	108.8	0.0	0	0	0	18
	Water	108.8	0.0	0	0	0	199
Flint	Urban	17.5	1.5	443	0	443	1508
	Transportation & Utilities	21.5	0.5	22	0	22	247
	Crop	16.3	371.9	366	124	490	518
	Pasture/Range	11.4	116.2	23080	97	23176	19362
	Orchards & Vineyards	4.7	20.7	9	4	14	143
	Nurseries	0	0.0	0	0	0	0
	Forest	6.5	19.8	178	10	188	9892
	Poultry Operations	115.4	0.0	0	0	0	197
	Dairy	0	0.0	0	0	0	0
	Hog Operations	115.4	0.0	0	0	0	37
	Water	115.4	0.0	0	0	0	205

Table 2.20 (continued). Mass loading SIMPLE model predictions for the Upper Illinois River Basin using the independent annual simulation mode by land use for each watershed.

Watershed	Land Use	Runoff (cm)	Sediment Yield (Mg)	Soluble P (kg)	Sediment-bound P (kg)	Total P (kg)	Area (ha)
Baron	Urban	19.6	0.3	56	0	56	169
	Transportation & Utilities	24.2	0.2	1	0	1	8
	Crop	18.2	130.6	81	48	129	108
	Pasture/Range	13.1	151.8	26908	190	27098	18976
	Orchards & Vineyards	5.8	30.2	10	7	17	126
	Nurseries	0	0.0	0	0	0	0
	Forest	10.5	19.7	570	20	590	19666
	Poultry Operations	123.7	0.0	0	0	0	148
	Dairy	0	0.0	0	0	0	0
	Hog Operations	123.7	0.0	0	0	0	6
	Water	123.7	0.0	0	0	0	7
Benton	Urban	15.7	1.1	73	0	73	278
	Transportation & Utilities	19.4	0.5	6	0	6	78
	Crop	14.2	34.1	178	8	186	284
	Pasture/Range	10.2	113.5	23566	91	23657	22703
	Orchards & Vineyards	4.2	0.7	0	0	0	7
	Nurseries	0	0.0	0	0	0	0
	Forest	6.2	13.9	236	14	250	13885
	Poultry Operations	113.3	0.0	0	0	0	123
	Dairy	113.3	0.0	0	0	0	18
	Hog Operations	113.3	0.0	0	0	0	29
	Water	113.3	0.0	0	0	0	207
River	Urban	17.5	0.1	30	0	30	101
	Transportation & Utilities	21.5	0.0	1	0	1	17
	Crop	16.4	3.2	35	0	35	49
	Pasture/Range	11.7	51.0	2460	23	2489	5669
	Orchards & Vineyards	0	0.0	0	0	0	0
	Nurseries	0	0.0	0	0	0	0
	Forest	6.6	13.3	119	7	126	6629
	Poultry Operations	115.4	0.0	0	0	0	11
	Dairy	115.4	0.0	0	0	0	3
	Hog Operations	115.4	0.0	0	0	0	5
	Water	115.4	0.0	0	0	0	79
Bord	Urban	15.8	8.6	25	4	30	96
	Transportation & Utilities	21.5	0.0	1	0	1	10
	Crop	18.4	5.1	8	0	8	13
	Pasture/Range	11.1	203.4	3865	92	3967	10172
	Orchards & Vineyards	0	0.0	0	0	0	0
	Nurseries	0	0.0	0	0	0	0
	Forest	6.1	22.5	382	0	404	22468
	Poultry Operations	115.4	0.0	0	0	0	38
	Dairy	0	0.0	0	0	0	0
	Hog Operations	115.4	0.0	0	0	0	5
	Water	115.4	0.0	0	0	0	190